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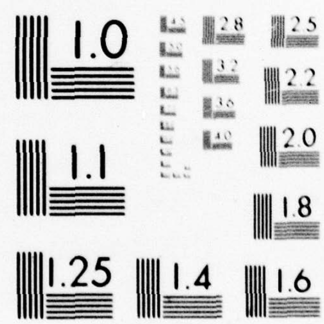

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FEASIBILITY STUDY OF DCS PALLETIZATION/MODULARIZATION CONCEPT

July 1979

Prepared for

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U.S. ARMY COMMUNICATIONS-ELECTRONICS
ENGINEERING INSTALLATION AGENCY
Fort Huachuca, AZ 85613

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The basic feasibility, probable scope, implications, and costs of implementing the Defense Communications System palletization/modularization concept are examined in the context of requirements for the worldwide present and future (1980's) DCS and the applicable capabilities, techniques, and technologies. Source materials for the study included relevent military documents, program reports and plans, and industry literature surveys, supplemented by visits to selected organizations and representative facilities.

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Under Contract DAEA18-72-A-0005, [redacted]

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Prepared by

10

W. J. Hodin, [redacted]
L. Graham,
J. S. Schaefer
A. Simmons

ARINC RESEARCH CORPORATION

CORPORATE HEADQUARTERS
2551 Riva Road
Annapolis, Maryland 21401

SANTA ANA BRANCH
1222 E. Normandy Place
Santa Ana, California 92702

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ABSTRACT

The basic feasibility, probable scope, implications, and costs of implementing the Defense Communications System palletization/modularization concept are examined in the context of requirements for the worldwide present and future (1980s) DCS and the applicable capabilities, techniques, and technologies. Source materials for the study included relevent military documents, program reports and plans, and industry literature surveys, supplemented by visits to selected organizations and representative facilities.

SUMMARY

Background

This study examines the feasibility and scope of applicability of a new palletization/modularization (P/M) concept for the equipment in the Defense Communication System (DCS) in the 1980s. The DCS employs a wide variety of equipment in a network of some 581 communication centers and supporting stations. The P/M concept is based on factory assembly, integration and checkout of DCS equipment in cabinets mounted on simple and sturdy aluminum pallets to facilitate transport and rapid installation, removal, and relocation as needed. The timely application of this P/M concept to the DCS has potential for significant benefits in that the DCS is programmed for transition from analog to digital transmission with extensive upgrades in equipments and sophistication (see DCEC TR 14-75, Engineering Concepts for the Future DCS).

Study Approach

The major objectives of the study were to demonstrate the feasibility or non-feasibility of the P/M concept for the DCS and to assess its scope of applicability throughout the DCS in the 1980s. To make these determinations, it was necessary to select a representative sample of DCS equipment for which data were readily available in the form required. For purposes of this study the equipments used in the Frankfurt, Koenigstuhl, and Vaihingen (FKV) Phase I and II upgrades, and those planned for the Digital European Backbone (DEB) Stage I, II, III, and IV upgrades, were selected as representative of the latest and next generations of DCS equipment (see Management/Engineering Plan for the Digital European Backbone, 5 October 1978).

While the DEB upgrade project will impact on only an estimated 25% of the total number of current DCS sites, the DEB data represent the best available concerning the functions and constraints of digital C-E equipment. Further, because the DEB is representative of a major technological advancement for the DCS, i.e., the transition from analog to digital DCS C-E equipment/systems, and has been identified by DCEC and CEEIA as representative of the major portions of DCS upgrades planned through the 1980s, it has been found appropriate to consider the DEB as representative of the basic technology that DCS systems will employ in the 1980s.

Study Results, Conclusions and Recommendations

1. Feasibility of P/M Concept for DCS – The P/M concept was determined on the basis of the study investigations and assessments to be an application of established technology and techniques that have been employed in operational military systems. The study concludes that the P/M concept is technically feasible for implementation within the DCS of the 1980s on the basis of the following considerations:

a. Module Design – No potential problems or unknowns; negligible risk
b. Producibility – No potential problems or unknowns; negligible risk
c. Transportability – Military contingency uncertainties; small risk
d. Interoperability – Military contingency uncertainties; small risk
e. Supportability – No potential problems or unknowns; negligible risk

2. Probable Scope of Applicability in the DCS – The applicability of the P/M concept to the worldwide DCS was projected from its hypothetical use in 1) the current FKV and DEB I subsystem of the DCS, and 2) the planned DEB II, III, and IV upgrades as detailed in the latest DEB Management/Engineering Plan. The types of functions that were upgraded or converted (analog to digital) in the FKV and DEB I were found to be compatible with the P/M concept, i.e., the equipments involved would fit the basic P/M envelopes.

Comparing these FKV and DEB I functions with similar functions presently employed across all DCS sites showed widespread application, as summarized in Table 1. This projection is consistent with DCA planning for the conversion of the DCS terrestrial transmission subsystem from analog to digital, wherein the FKV and DEB I represent the initial steps. Thus, this projection indicates the proportion of the DCS sites that could use the P/M implementations of FKV and DEB I functions, assuming that the P/M modules were available.

TABLE 1. POTENTIAL CURRENT APPLICATION OF P/M CONCEPT

Examples for Functional Modularization	Potential Application (Pct.)	
	FKV and DEB I	All DCS
Transmission medium (line-of-sight radio)	100	63
Voice multiplex	100	69
DCS electrical power	100	77

3. Cost-effectiveness of the P/M Concept – Using the cost estimating methodology as prescribed by the Defense Communications Agency Circular (DCAC) 600-60-1 and standard cost data, the cost-effectiveness of the P/M concept was compared with current DCS practices in representative scenario situations. Two scenarios, A and C, of six cited in the study SOW, were found to collectively include all transition activities so that their costs are indicative of possible benefits as shown in Table 2.

TABLE 2. COST EFFECTIVENESS COMPARISON OF DCS PRACTICES AT/FOR REPRESENTATIVE INDIVIDUAL DCS SITES

Cost Elements	Scenario-A ($)		Scenario-C ($)	
	Current	P/M	Current	P/M
Integration & Assembly	63,963	32,311	-	-
System/Project Mgmt.	115,133	77,213	-	-
Oper'l Site Activation				
– Disassemble old eqpt.	63,963	32,172	-	-
– AI&C new site eqpt.	255,851	128,689	54,437	41,094
Transportation	109,797	85,882	-	-
Summary	608,707	356,267	54,437	41,094

4. Recommendations – It is recommended that for the 1980s DCS upgrade program, a simple sturdy lightweight pallet be used for the mounting of equipment cabinets to house DCS equipment in order to facilitate their assembly, integration, and check-out, to facilitate their shipment/transport as a complete module, and to facilitate their rapid installation and/or removal and relocation as needed. Technology advances in the 1990s timeframe may lead to higher levels of module integration for the DCS.

CONTENTS

(Supplements to this report, under separate cover, are an Executive Summary and Annex A, a Technical Design Handbook. Both have the same publication number as this report.)

Chapter 1

INTRODUCTION/OBJECTIVES

1.1 BACKGROUND

The Defense Communications System (DCS) provides long-haul, common user, switched network communications services worldwide to DoD and other U.S. Government agencies. The DCS employs a wide variety of equipment installed in a network of communication centers and supporting stations. This equipment ranges from the older tube-type and analog transmission systems to the newer solid-state digital systems. The use of different combinations of older and newer systems is typical in DCS centers, being determined by local upgrades to meet service needs and priorities. Consequently, the assemblage of communication systems and their component black boxes varies greatly from one installation to another.

In addition to the technological mix of communication equipments in a DCS center, a wide range of electronic equipment is needed to provide supporting services for the operation and and maintenance activities. These units provide switching, testing, controlling, augmenting, enabling, and/or monitoring services to sustain the primary communication services of the DCS center. The diverse nature of the electronic units and of their relationships with the primary communication units has always posed problems in grouping the communications-electronics (C-E) units into modules for transportability, handling, installation, and operation and maintenance access.

The U.S. Army Communications Command (USACC) and its subcommand, the USA Communications-Electronics Engineering and Installation Agency (USACEEIA), have over the years engaged in a program of C-E module design, development, and improvement to enable faster installation and activation of communication centers, and subsequent take-down and relocation of DCS centers to other sites. Examples of three modular, long-line C-E systems and their respective technologies are listed below. Two of these systems, the AN/TRC-90 series and the AN/FRC-109, are in current use within the DCS, while the third system, the AN/TRC-29, was functioning in Korea as late as 1976. These systems are:

Nomenclature	Technology
AN/TRC-29	Tube
AN/TRC-90 series	Tube and Analog Solid State
AN/FRC-109	Analog Solid State

The AN/TRC-29 was configured into RF and multiplex packages similar to large steamer trunks. The equipments were mounted in the trunks on runners to permit access for maintenance. These trunks could be moved and positioned by as few as two men without difficulty. The trunks were cabled together onsite to make up to a 96-channel line-of-sight (LOS) microwave system that could be made operational (excepting antenna erection, power plant emplacement, and facilities construction)

in less than an hour. No special facility preparation, such as environmental equipment, was required. The TRC-29 had built-in blowers for cooling and the necessary built-in test equipment required to verify system performance. This system represents a successful application of a P/M concept during the tube technology era.

The AN/TRC-90 series started with the packaging in an S-280 shelter of the AN/TRC-80 RF system (tube technology) and the MX-106 and AN/FCC-69 multiplex systems (solid state) to meet short-term contingency requirements. Initially, the system was a 1-kilowatt diversity tropospheric scatter radio system with 24 VF and 16 data channels. The series then progressed through several model changes to an all-solid state 10-kilowatt quadrature diversity tropo system with 48 VF and 32 data channels. The AN/TRC-90 series demonstrates the simple application of technological improvements that did not change basic functions, i.e., RF or multiplex functions, but which instead reduced them in size and weight while increasing their respective capabilities. Furthermore, each new model added to the series was compatible with previous model series equipment.

The AN/FRC-109 is configured from various RF functional modules to meet specific site requirements. For example, the basic FRC-109 modules can be configured for space, frequency, or quadrature diversity modes, and as a relay or terminal system. It is believed that this equipment was configured by equipment cabinet (or 19-inch rack) and interconnected as required at the vendor plants. The assembled units were then shipped to field sites for installation. The FRC-109 is smaller and lighter than the TRC-29, while providing a greater channel capacity (1200 channels for the FRC-109 versus 96 for the TRC-20).

Historically, then, the application (i.e., feasibility) of palletization/modularization (P/M) concepts for LOS and tropo systems with traffic capacities in excess of 1000 channels has been demonstrated. It thus remains to demonstrate the feasibility and subsequent application of a P/M concept to the specific equipment to be found in the current and future DCS.

1.2 PALLETIZATION/MODULARIZATION CONCEPT

The P/M concept employs C-E modules that permit rapid deployment, installation, and activation as well as rapid recovery and relocation. The C-E modules would be pallet-mounted, and each would provide a significant functional capability. Thus a suitable group of such modules could serve as a particular DCS site, or at least a significant part thereof. The makeup of such equipment modules will be governed by engineering and design parameters required by the DCS mission in context with transportability and structural considerations. Transport constraints will impact the size and shape envelopes of the modules.

The modules would be designed with standardized dimensions and connections so that they could be easily handled and transported, and rapidly and interchangeably installed in, operated in, and recovered from prefabricated buildings and permanent structures as well as specified vans and expandable shelters. DCS installations would be activated by placing the modules in buildings, vans, or shelters and then interconnecting their physical and electrical interface elements. Thus the P/M concept would improve responsive flexibility for DCS equipment deployments as well as for recovery and relocation. To the extent possible, a single pallet design is to be sought that will accommodate the maximum number of module configurations.

1.3 APPLICATION OF CONCEPT

This study examines the feasibility and scope of applicability of a palletization/modularization (P/M) concept for C-E equipment in the Defense Communications Systems. In accordance with the study statement of work, feasibility is examined for those DCS equipments that were identified as being in current use or planned for use in the 1980s. In light of this scope, the configurations and interfaces of the equipments to be palletized are largely determined already. It is expected that a follow-on study to examine the feasibility and configuration of modules for third generation (1990s) digital equipment could be free of many of the conceptual constraints of the current study. Such a study of 1990s possibilities could consider many new technologies, allowing smaller equipment items, new interconnect techniques and packaging architecture, etc., to implement modules with increased levels of factory assembly and reduced onsite integration and checkout time. This in turn could lead to wider applicability of the P/M concept to more station configurations than considered in this study of P/M for the 1980s upgrade process. The resultant deployed 1990s DCS could, as a result, provide a higher degree of flexibility in site redeployment, contingency reconfiguration, and resource recovery. The requirements for and characteristics of a pallet/module configuration developed to address entire sites, rather than partial upgrades, and to take advantage of future technologies, could be substantially different from those derived in the current study. The subsequent savings, in both deployment time and expense, could be substantial.

The P/M concept advocates factory assembly, checkout, and shipping of functional C-E and C-E support equipments on pallets (i.e., supporting structures) in order to facilitate rapid installation, recovery, and relocation of the equipment. A group of such equipment along with the mounting pallet, is termed a module. The early application of this P/M concept to the DCS has potential for significant benefits in that the DCS is programmed for transition from analog to digital transmission with extensive upgrades in equipments and sophistication. A key example of such upgrades is described by the Management/Engineering Plan (MEP), dated 5 October 1978, for the Digital European Backbone (DEB) system of the DCS. DEB upgrade objectives stated therein to be accomplished by 1985 are indicated below, to illustrate their nature and significance to the world-wide DCS:

a. Provide the capability of meeting digital transmission requirements of subsystems such as Secure Voice Improvement Program, AUTODIN II, etc.

b. Provide bulk encryption for all links of this subsystem.

c. Maximize terrestrial wideband digital access paths for the Defense Satellite Communications System (DSCS) traffic to enhance the survivability of the entire DCS.

d. Convert certain DCS line-of-sight radio repeater sites to unattended operation.

e. Enhance the survivability of the DCS by maximizing alt-routing capabilities.

f. Extend digital DCS service to new user locations.

g. Provide a tactical interconnect capability at selected DCS locations.

h. Deactivate selected DCS sites and links in response to changing user requirements or where lease service is demonstrated to be more cost-effective.

The MEP for the DEB goes on to say that the present DCS wideband subsystem is largely composed of equipment that are obsolete in design, unreliable, and extremely expensive in terms of logistic support requirements. Cited as examples are such specific equipments as the Siemens Halske (SH) EM-120/400, FM-12/800, and FM-120/8000 LOS radios and SH VZ-12 multiplex equipment. In addition, there are obsolete AN/GRC-66 equipments and FCC-18 and FCC-32 multiplexers to be replaced. The magnitude of this DEB upgrade to meet the noted objectives, and the implications for the extension of such objectives across the overall DCS, warrants an early assessment of alternative upgrade implementation approaches. General upgrade practice, as illustrated in Figure 1-1, has typically involved site-by-site engineering, layout, and planning, followed by the delivery of collections of upgrade equipments, cables, cabinets, etc.; and teams of technicians as needed for assembly, installation, and checkout on-site. Such practices contribute little to the responsive flexibility of the DCS. The P/M concept offers a hardware systems approach to a versatile DCS network with rapid installation and recovery benefits.

1.4 STUDY OBJECTIVES

The objectives of this study are to:

a. Define and detail the DCS C-E palletization/modularization concept as necessary, and determine its functional feasibility in responsive deployments of DCS resources during the 1980s upgrade process.

b. Determine the extent of expected palletization applications in the DCS network by identifying standardization and installation constraints and comparing them with DCS C-E equipment mounting, handling, and transportation requirements in the 1980s.

c. Develop a set of design criteria and parameters for the minimum variety of pallets that will satisfy the DCS requirements and applications scoped in "b", above.

d. Estimate procurement costs of the pallets defined in "c", and compare selected operational costs of the modules and existing DCS installation and operating practices.

e. Recommend design guidelines for future DCS C-E equipments to facilitate and improve the implementation and use of the palletization/modularization concept in the DCS network in the 1980s and 1990s.

To accomplish the objectives of this study, the following tasks, as stated in the SOW, were performed.

- <u>Task I – Feasibility Analysis of P/M Concept</u>

  The contractor shall determine the basic feasibility of, and define the probable scope of applications for, the palletization/modularization concept as applied to DCS C-E resources.

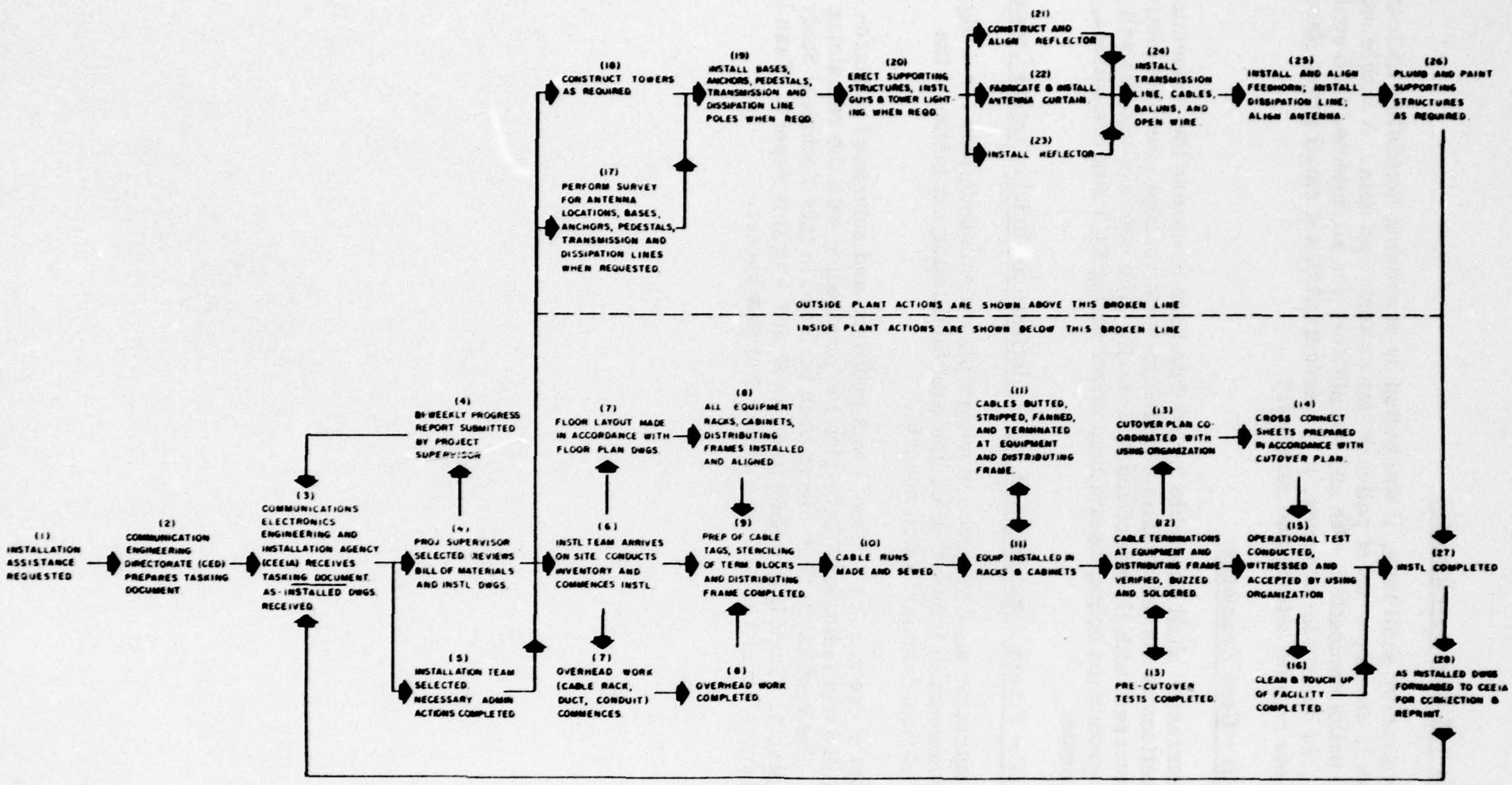


Figure 1-1. Sequence of General Installation Procedures for Communication System Upgrade (Reproduced from CCTM 105-50-21)

- **Task II – Design Development**

  The contractor shall then, if warranted by promising feasibility indicators in Task I, develop a set of pallet design criteria and data. A single universal pallet compatible with and satisfactory for all selected DCS applications...is desirable; however, it is recognized that a small group (family) of pallets may be determined necessary.

- **Task III – Cost Evaluation**

  The contractor shall assemble a cost data base to assess the economic implications of the palletization/modularization concept after completion of or concurrent with the execution of Task II. The cost evaluations will include pallet production costs, operational costs during DCS site transitions, and other costs.

- **Task IV – Future Application of the Palletization/Modularization Concept**

  The contractor shall project and determine recommendations for design improvements to future C-E equipments facilitating expansion of the palletization/modularization concept.

The report of the results of Task I was prepared and submitted in March 1979. Concept feasibility was indicated. Direction for proceeding with the remaining tasks was provided. The results of Task I have been included in this Technical Study Report as Chapter 2. Task II is documented as Annex A of this report. Task III is reported as Chapter 3 and Task IV as Chapter 4 of this report.

Chapter 2

FEASIBILITY ANALYSIS OF P/M CONCEPT

2.1 TASK OBJECTIVE

The objective of this task was to determine the basic feasibility of, and define the probable scope of applications for, the palletization/modularization concept as applied to DCS C-E resources for the 1980s upgrade process. Task elements, as defined in the statement of work, included:

a. Equipment survey. Perform a survey of DCS equipment in use and planned for future use in the 1980s, and assess how those equipments lend themselves to incorporation in the palletization/modularization concept. Equipments shall include basic C-E equipment as well as maintenance, administrative, and support items which could be incorporated into the palletization/modularization concept.

b. Technology survey. Perform a survey of recent government and commercial developments in the palletization and related fields, and assess their possible application to the palletization/modularization concept.

c. Performance trends. Perform a survey of DCS equipment specifications and practices (MIL-STD-188 series applies). After performing the survey, assess the impact of specification and practice trends upon implementing the palletization/modularization concept.

d. Constraints. In evaluating the applicability of the palletization/modularization concept, identify and assess the impact of operational and other constraints.

e. Previous studies. Perform coordination with the military departments (contact points to be provided by the contracting officer) to assess the applications and limitations of previous Army, Navy, Air Force, and Defense Communications Agency studies and data accumulations pertaining or relating to the palletization/modularization concept.

f. Ongoing programs. Identify and assess programs within the military departments which have objectives similar to those of the palletization/modularization concept. Specifically to be included is the ongoing TRI-TAC program.

g. Transport. Determine standard transport parameters and constraints for air, sea, and land movements of DCS C-E equipment and assess their impact on the palletization/modularization concept.

h. Fixed and mobile DCS C-E applications. Determine the following:

1) Present permanent and prefabricated building practices and characteristics representative of those utilized in DCS C-E applications, and assess their impact on the palletization/modularization concept.

2) Characteristics of the specified vans and shelters (RFP para. 3.3) and assess their impact upon the palletization/modularization concept. Due consideration will be given to RFP para. 3.1.2.

3) Partial applications of the palletization/modularization concept; e.g., module configurations being developed for certain types of line-of-sight microwave equipments or terminals, but not for others. Large, unwieldy systems, such as the present generation AUTODIN Switching Center, will not be considered.

2.2 TASK APPROACH

The major objective of Task I was to demonstrate the feasibility or non-feasibility of the palletization/modularization concept for the DCS and to assess its scope of applicability throughout the DCS. To make these determinations, it was necessary to select a representative sample of DCS equipments for which data were readily available in the form required. For purposes of this study the equipments used in the Frankfurt, Koenigstuhl, and Vaihingen (FKV) Phase I and II upgrades, and those planned for the Digital European Backbone (DEB) Stage I, II, III, and IV upgrades, were selected as representative of the latest and next generations of DCS equipment.

While the DEB upgrade project will impact on only an estimated 25% of the total number of current DCS sites, the DEB data represent the best available concerning the functions and constraints of digital C-E equipment. Further, because the DEB is representative of a major technological advancement for the DCS, i.e., the transition from analog to digital DCS C-E equipment/systems, and has been identified by DCEC and CEEIA as representative of the major portions of DCS upgrades planned through the 1980s, it has been found appropriate to consider the DEB as representative of the basic technology that DCS systems will employ in the 1980s. Finally, it is assumed that while various functional parts of DEB C-E equipment, e.g., the RF and multiplex equipments, will be improved through technology, the interface requirements between such basic functional equipments and other elements of the system will remain constant or at least compatible. This assumption is based on the premise that DCS budget limitations preclude a sudden, system-wide upgrading of all equipments. The transitional upgrade of selected portions of the system over a period of time will thus require that interface compatibility with existing system elements be maintained, thereby imposing a relatively stable interface structure on new equipments.

The study approach to determine the basic feasibility of, and to define the probable scope of applications for the P/M concept in the DCS, is illustrated in Figure 2-1. The principal subtasks and activities involved in the approach are as follows:

a. Assess P/M concept for current DCS:

1) Select representative sites, based on DCA-provided data on the mix of site types in the current DCS and on the FKV/DEB system of the DCS.

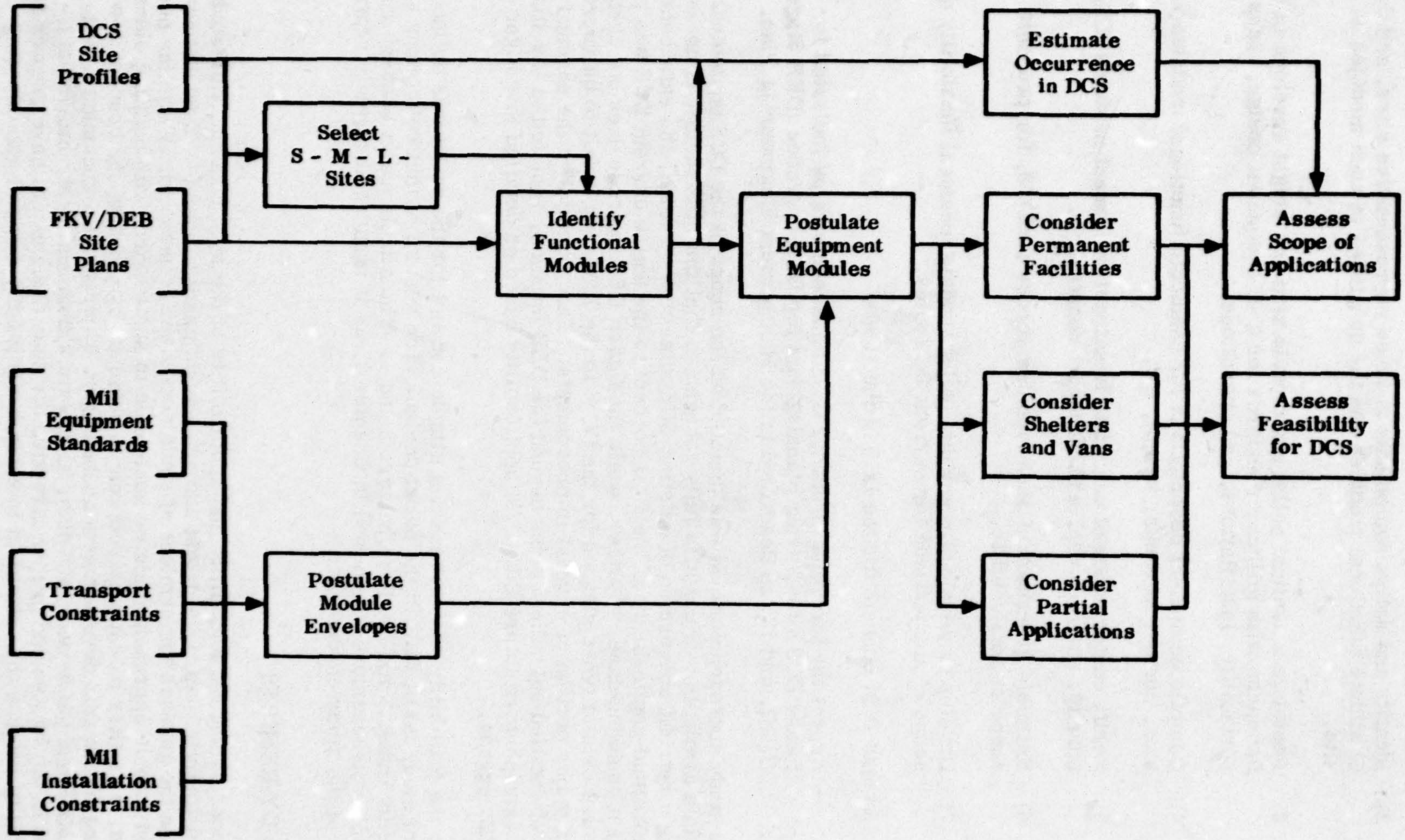


Figure 2-1. Applications Study of P/M Concept for DCS

2) Identify and define equipments at those representative sites, and define candidate functional modules and the quantities of such modules at each site.

3) Postulate a nominal pallet and module size and weight envelope in conformance with military standards for C-E equipment design, transportability, installations, and operations.

4) Compile equipment descriptions for candidate functional modules: size, number of racks, weight, etc.

5) Verify conformance of candidate functional equipment modules with facility, shelter, van, and transport constraints.

6) Estimate quantities of such modules across the DCS, for probable scope of applicability.

7) Develop conclusions regarding pallet/module technical feasibility and scope of applications for current DCS sites.

b. Assess P/M concept for the DCS of the 1980s:

— Repeat the foregoing procedures and assessments as indicated for future DCS sites, using planning data for DEB upgrades (DEB Stages II, III, and IV) as described in the Management/Engineering Plan.

The study approach pursued was dictated by the scope of the DCS equipment and planning data available. While it is fully recognized that the Government is not contemplating a retrofit conversion of existing DCS sites to P/M form, the extrapolation of the theoretical applicability of the P/M concept to the entire current DCS was performed as a bounding case. Further, while the future DEB upgrade does not encompass all equipment or site types planned for the DCS in the 1980s, it is felt to be representative of a major portion of planned improvements. That, along with the absence from the study of detailed equipment plans beyond the DEB upgrade, resulted in the study approach extrapolating future DCS P/M applicability based on detailed investigation of the DEB upgrade.

For the feasibility analysis task, a simple concept for the pallet was defined. Subsequent study tasks refined the pallet design. The results of that refinement are described in Annex A and used in Chapters 3 and 4. The simple pallet concept used for feasibility assessment is retained in Chapter 2, as it is more accurately representative of the study chronology.

2.3 STUDY RESULTS

In considering the feasibility and applicability of the P/M concept, this study is oriented primarily toward the latest and subsequent generations of C-E equipment rather than the general complement of equipment already installed. While the preassembled module approach might be applicable to some extent with existing older equipment, a greater potential payoff can be achieved by planning the concept now and guiding future DCS developments accordingly. Current DCS documents, e.g., the DEB MEP and the 5-year DCS plan, anticipate substantial restructuring of C-E equipment in the future; and proper direction for such designs will have greater cost and flexibility returns than attempts to extensively modify and palletize existing equipment for removal and relocation.

To assess the basic feasibility of the P/M concept, three FKV/DEB sites were identified and analyzed. C-E equipment size, weight, and power data were compiled; candidate functional groupings were identified for possible palletization; a conceptual pallet and equipment rack was structured to conform to transportation and equipment-mounting requirements; and palletized configurations were established for current and future C-E equipment at the three sites. The probable scope of applicability of the candidate P/M concepts was assessed by relating the functional modules identified at the three example sites to the frequency of occurrence of similar equipment functions throughout the DCS.

2.3.1 DCS Equipment Survey

A basic consideration in evaluating the potential feasibility of the P/M concept is the determination of the kinds of equipment that could be palletized as modules for use in the DCS. DCEC TR 14-75, Engineering Concepts for the Future DCS, postulates that the present analog equipment in the DCS will be replaced by digital equipment, and that solid state technology and microprocessor controls will significantly reduce weights and volumes. Thus, any survey of current DCS inventory equipment should be oriented toward digital equipment as representative of DCS objectives. The Digital European Backbone system sites and their digital equipment as shown in TM 11-490-4 and the DEB Management/Engineering Plan represent a significant segment of the worldwide DCS. Further, the portions of the DEB involved in the FKV (Frankfurt, Koenigstuhl, and Vaihingen) Phase I and II system upgrades exemplify applications of current digital equipment. As noted in TM 11-490-4, the FKV/Phase I system was the pilot program for DCS digital communications. FKV/Phase II and DEB/Stage I continue the program and provide a digital system extending from Frankfurt, Germany to Coltano, Italy. Later DEB stages (II, III, and IV) will extend this digital system within the DCS in Europe.

While there are some differences between the FKV and DEB Stage I systems, both use basically the same multiplex (MUX) and radio equipments. Each has the TSEC/CY-104 multichannel ciphony system as the basic first level MUX. The CY-104, as used in FKV/Phase I, accepts up to 24 four-wire standard voice channels. The CY-104, as used in FKV/Phase II and DEB/Stage I, accepts up to 24 four-wire voice channels or (by module change at the channel level) a combination of voice channels and data signals. Up to five full-duplex data signals at speeds up to 64 kilobits per second (kbps) may be transmitted with the voice channels. The FKV/Phase I uses a separate first level MUX (T1WB1) to provide up to eight full-duplex data channels at speeds up to 60 kbps. The output of all first level MUXs is 1.544 megabits per second (Mbps). This output is a bipolar signal and is a U.S. commercial standard designated T1 for tariff purposes.

The second level MUX units of the FKV/Phase I and DEB/Stage I are redundant T1-4000s (AN/FCC-97). (The T1-4000s used in the FKV are part of a multiplexer group nomenclatured OB-79(V)/FSC.) The second level MUX will accept up to eight full duplex T1 (1.544 Mbps) signals and time-division-multiplex them into a three-level partial response signal at 12.6 Mbps. The latter value is then applied to the baseband of a microwave radio.

The FKV uses AN/FRC-162 radios and DEB/Stage I employs the AN/FRC-162 and AN/FRC-165 types. The AN/FRC-162 and -165 radios are identical, except that the -165 has an amplifier to raise the -162's transmit power (0.5 watt) to 5 watts. These radios employ a space diversity receiver and have a hot standby transmitter

in order to provide the system reliability required. The radios also provide an auxiliary baseband input which accepts a maintenance coordination circuit (MCC) for link coordination and (where required) remote alarm information for the alarm monitor group (AMG). The MCC input accepts frequencies of 300 to 3000 Hz, and the AMG input accepts frequencies from 300 to 8000 Hz.

If no data signals are required, the maximum number of voice channels available on an FKV or DEB/Stage I link is 192, i.e., eight groups of 24 channels. If high-speed data capability is required, the FKV/Phase I system sacrifices 24 voice channels to provide eight data circuits with a maximum rate of 50 kbps each. FKV/Phase II and DEB/Stage I links lose only one voice channel for each high-speed data circuit.

Both the FKV/Phase I and DEB/Stage I radio links are designed to provide 99.99 percent availability, based upon the link configuration and equipment mean time between failure and mean time to repair.

The DEB Stage II, III, and IV upgrades will use DRAMA (Digital Radio and Multiplex Acquisition) equipment, i.e., the AN/FRC-170 series radios (which had been initially designated as the AN/FRC-163) and the TD-1193( )/F and TD-1192( )(P)/F multiplexer-demultiplexer units for second and first level MUX, respectively. These DRAMA equipments are representative of the next generation of digital equipment that would be used in other DCS sites in their planned upgrades. Since these equipment are new, production design details on their size, weight, and power are not firm. Best indications, drawn from specifications and discussions with Government and manufacturer personnel, are that they will be similar to those of the digital equipment in current use in the FKV/DEB Stage I sites. Thus the major space, weight, and power reductions to be realized by converting from analog to digital equipment are largely in evidence in these sites already, and further gains for the next generation (DRAMA) equipment will be small. Accordingly, the development of P/M concept modules, based on the current digital equipment, should be applicable to DRAMA upgrades and possibly to other digital communications equipment as developed.

2.3.1.1 Selection of Representative DCS Sites

Selection of representative DCS sites for this study was based on a functional survey conducted at the Defense Communications Engineering Center at Reston, Virginia, using a DCA microfilmed data base that describes 581 DCS sites worldwide. Table 2-1, as developed from film data, shows a composite tabulation of the various services provided currently by each military DCS site. Table 2-2 shows a representative page of the functional survey data from which Table 2-1 was compiled. A complete listing (27 pages) of the survey data appears in Appendix A.

From Table 2-1 it can be seen which functions are most common, as well as their relative numbers. For example, line-of-sight land-radio equipment is at 64% of all DCS sites (373 of the 581 total). DCS electrical power generating equipment is deployed at 77% of all sites, and voice multiplex equipment at 69%.

Recognizing that DCS sites are equipped to meet different service requirements by the separate MILDEPs in a wide variety of facilities worldwide, it is not possible to readily designate "standard" sites. However, for purposes of this study, it was assumed reasonable to consider DCS sites to be of three levels of complexity and size: small, medium, and large.

TABLE 2-1. DCS SITE PROFILE SUMMARY

DCS Site Equipments and Facilities	Number of Installations So Equipped					
	Code	Army	Navy	AF	Total	Pct.
Traffic Switches - Voice						
AUTOVON Switch	SCA	4	1	10	15	2-1/2
AUTOSEVOCOM Switch Automatic	SVS	6	5	7	18	3
AUTOSEVOCOM Switch Manual	SVX	28	9	45	82	14
Voice Switch, Automatic, Other than AUTOVON	TSB	5	1	11	17	3
Voice Switch, Manual	TSM	10	1	11	22	4
Traffic Switches - Record						
Digital Switch, Automatic, Other than AUTODIN	ADR	2	2	0	4	<1
AUTODIN Switch	DIN	6	3	8	17	3
Data Relay, Manual	MDX	2	3	1	6	1
Teletype Relay, Automatic	TAX	0	0	1	1	<1
Teletype Relay, Manual	TMX	4	11	3	18	3
Transmission Media						
Coaxial Landline	CLX	4	1	3	8	1-1/2
Submarine Cable	CSX	4	0	2	6	1
HF Receiver Facility	HRX	3	18	6	27	5
HF Transmitter Facility	HTX	3	19	6	28	5
Line-of-Sight Radio (Land)	LSX	140	73	160	373	64
Landline Wire Cable	LLC	29	9	27	65	11
DCS SAT Earth Terminal	SYT	8	6	10	24	4
DCS Satellite	SAT	0	0	0	0	-
Tropospheric Scatter	TRX	45	5	83	133	23
Support Facilities						
CRYPTO (online) Facility	BOR	45	20	58	123	21
Voice Multiplex	MUX	139	77	183	399	69
DCS Electrical Power	PRX	174	85	188	447	77
Patch and Test Facility	PTF	69	59	120	248	43
Technical Control Facility	TCX	62	21	57	140	24
DCS Site Installations (MILDEP Total)		211	102	268	581	100

TABLE 2-2. EXAMPLE OF DCS SITE PROFILE

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(US/CZ)																								
1							X								X					X	X	X	X	X
2													X		X						X		X	
3														X	X						X	X	X	
4															X							X		
5															X						X			
6			X																	X				
7																			X		X		X	X
8			X																	X				
9		X																		X		X		
10				X																		X		
11																			X		X		X	
12																			X		X		X	
13					X														X		X		X	X
14																			X		X		X	
15																			X		X		X	
16																			X		X		X	
17			X																	X				
18																			X		X		X	
19																			X		X		X	
20																			X		X		X	
21			X																	X				
22			X																	X				
23																			X		X		X	
24																			X		X		X	
25																			X		X		X	
(cont.)																								

NOTE: A complete collection of Site Profiles is contained in Appendix A.

Small-configuration DCS sites were defined as those having only a single medium of transmission and a DCS electrical power system. Accordingly, a review of the individual DCS site profiles disclosed the following numbers of current sites limited to the respective single-transmission medium.

Transmission Medium	Army	Navy	A.F.	Total	Pct. of DCS Total
Coaxial Landline	0	0	0	0	-
Submarine Cable	0	0	0	0	-
HF Receiver	0	0	0	0	-
HF Transmitter	0	0	0	0	-
Line-of-Sight Radio	16	9	33	58	10
Landline Cable	1	0	0	1	-
Satellite Terminal	0	0	0	0	-
Tropo Scatter Radio	20*	0	6	26	4

The line-of-sight radio sites (LSX) of the minimum configuration level are widely distributed across the DCS and in sufficient numbers so that one of these could be selected as a representative small (S-type) DCS site. Further, since 64% of all DCS sites include the LSX function, the findings regarding such an S-type site would be of interest with respect to a large number of sites. Based on information in the DCA-provided manual for the FKV/DEB Stage I sites in Europe, Melibokus is such a site and was selected as the S-type site for this study.

Definition of a medium size (M-type) DCS site assumes that it will have added capabilities beyond an S-type, such as multiplex (MUX), patch and test (PTF), and/or technical control (TCX). It is recognized that these added functions are often associated with added transmission capabilities (tropo, landline, etc.). For this study however, limitation of potential sites to FKV/DEB reference sites leaves only those using only LOS transmission (LSX). Further, these reference sites of nominal medium-to-large size all have crypto capability (BOR). The review of DCS site profiles shows the following numbers of sites with the noted functions:

Function	Army	Navy	A.F.	Total	Pct. of DCS Total
1. LOS & MUX, PRX, PTF	38	18	35	91	16
2. LOS & MUX, PRX, TCX	15	1	2	28	5
3. LOS & MUX, PRX, PTF, TCX	0	1	0	1	-
4. LOS & BOR, PRX, PTF	0	0	0	0	-
5. LOS & BOR, MUX, PRX, PTF and/or TCX	5	4	3	12	2

---

*Recent data indicate that only 4 of these TRX sites remain operational under Army jurisdiction. No substantial impact on study results.

DCS sites with LOS transmission and MUX, PRX, PTF, and/or TCX capabilities (types 1, 2 and 3, above) were found to comprise 21% of the total. The nearest comparable sites in the FKV/DEB system were of the type 5, above, which have crypto (BOR) capability in addition to the other functions. (Note that type 5 is a subset of types 1, 2, and 3, and findings for site type 5 are therefore of relevance to at least 21% of current DCS sites.) The actual site selected as such an M-type is Vaihingen.

For the large (L-type) sites, the greater capability sites in the FKV/DEB Stage I network (Frankfurt and Stuttgart) provide reasonable examples. It was also noted in reviewing European Telephone System details that both sites will be major tandem switching centers. For this study, Frankfurt was arbitrarily selected from the two as the example L-type site.

Figures 2-2, 2-3, and 2-4 show the configuration of the digital equipment currently installed at Melibokus, Vaihingen, and Frankfurt, respectively.

2.3.1.2 Equipment Characteristics and Functional Groupings

Equipment characteristics for current and future configurations of the selected sites were extracted from Government-furnished documents on the DEB: TM 11-490-4; the Management/Engineering Plan (MEP) for the DEB; and specifications for the AN/FRC-170, TD-1192, and TD-1193 (DRAMA radio and multiplexers).

The primary functional elements of the DEB include the following:

- RF transmitter/receiver, digital
- First level multiplex, digital
- Second level multiplex, digital
- Patch and test facilities
- Fault alarm system
- Uninterruptable power supply (UPS).

TM 11-490-4 defines the equipments currently performing these functions in the FKV/DEB system, and the MEP lists various combinations of these functional elements for each individual site in the DEB upgrade. The functional elements are specified by site to meet that site's specific mission. Ancillary and support equipment are added by site, as required, but are not defined in the documentation on hand. Each functional element may be implemented by one or more of several nomenclatured equipment types. For example, the RF functional element includes the current AN/FRC-162 and AN/FRC-165, the future AN/FRC-170, and others. Thus, each site is tailored by its specific RF requirements for reliable communications to the next site or sites, and by channel requirements, e.g., from 24 to 192 channels.

An examination of the various functional elements, and the equipment types within these elements (as shown in TM 11-490-4), illustrates that each equipment

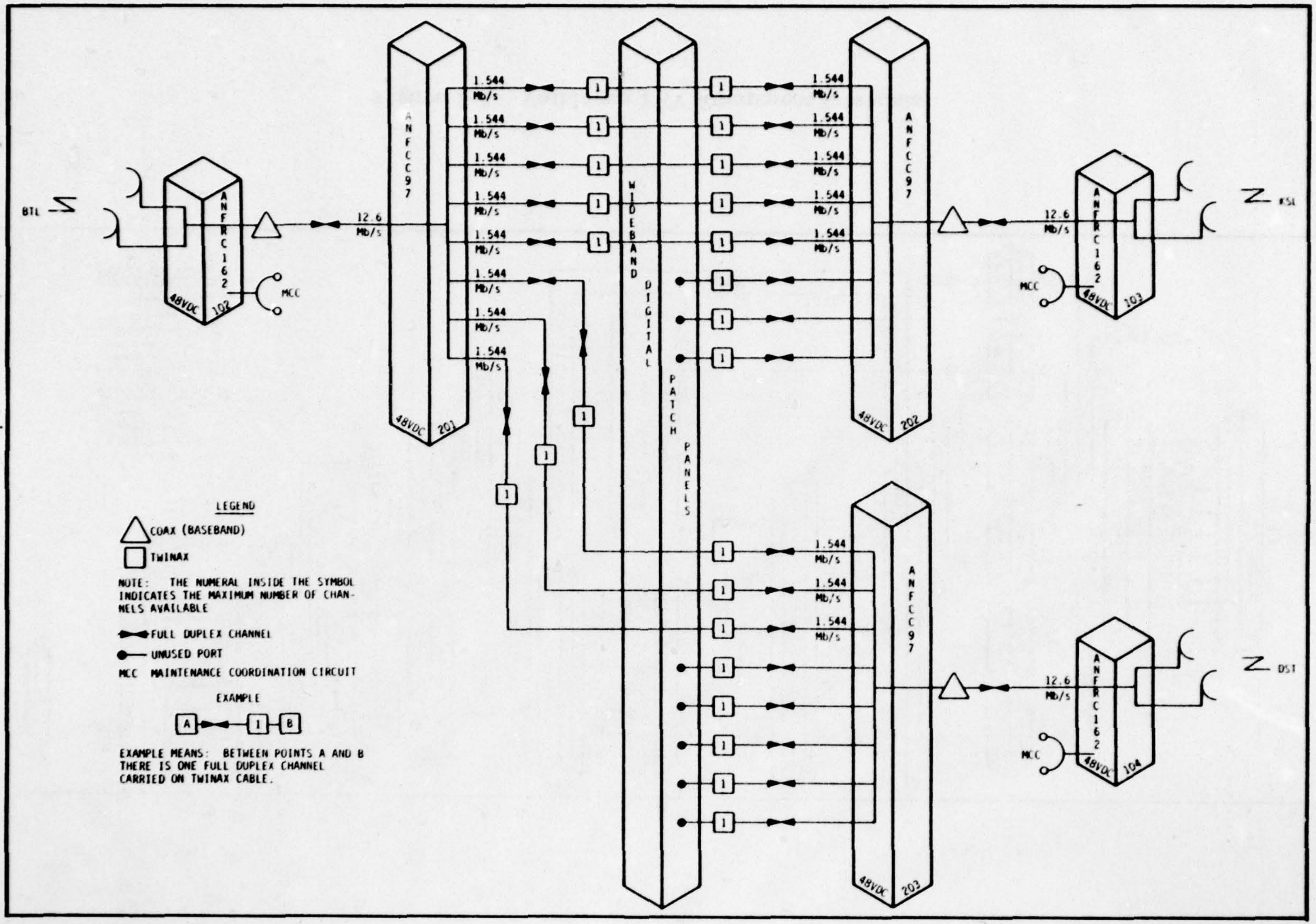


Figure 2-2. Melibokus FKV Equipment Interface

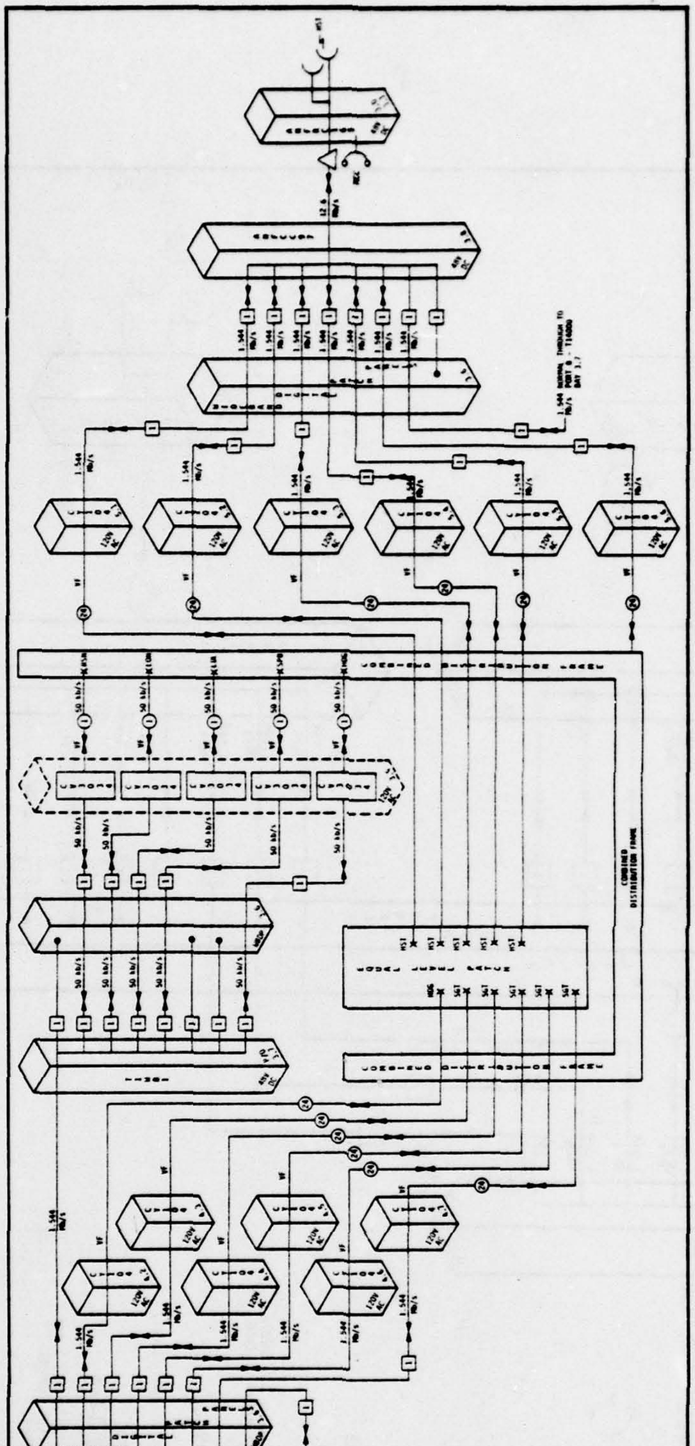


Figure 2-3. Vaihingen FKV Equipment Interface

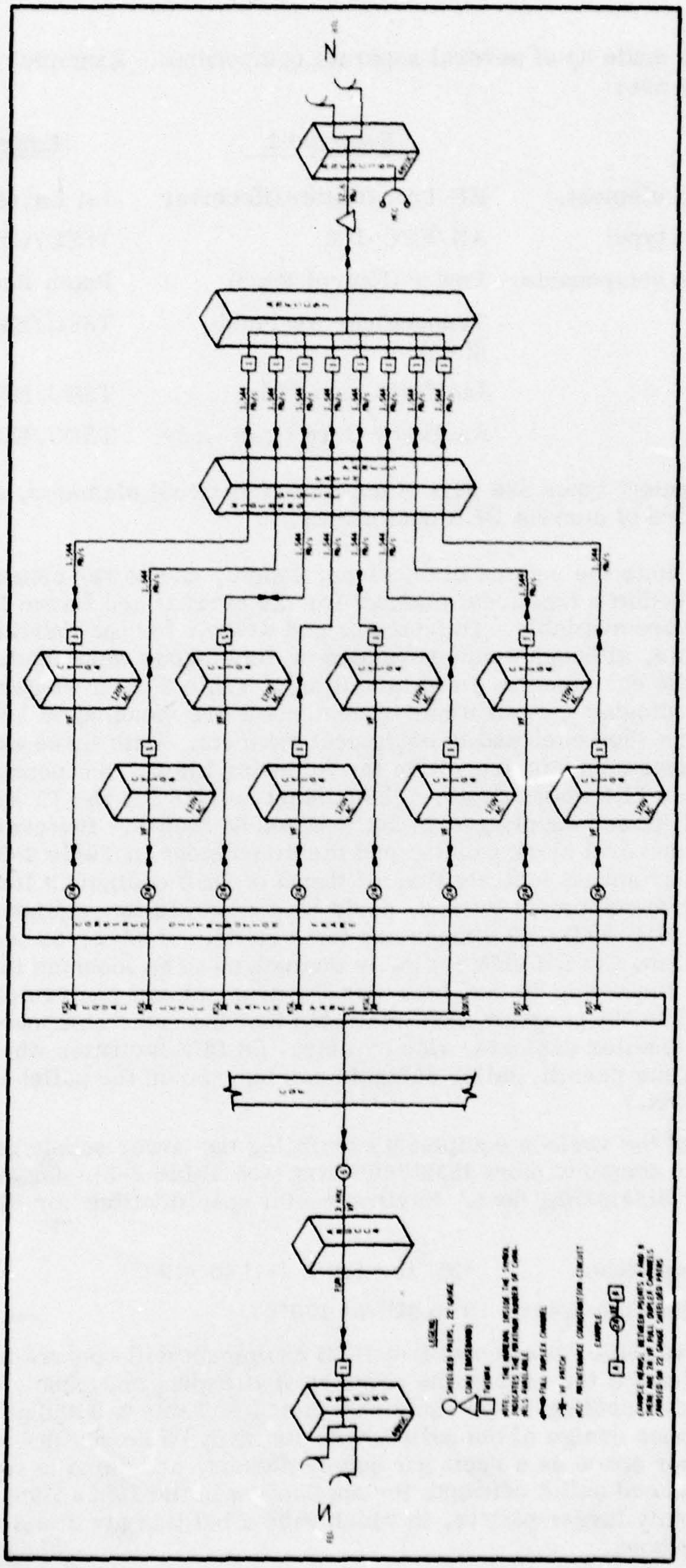


Figure 2-4. Frankfurt FKV Equipment Interface

type is typically made up of several separate components. Examples of DEB equipment types are:

	Example 1	Example 2
Functional element:	RF Transmitter/Receiver	1st Level Multiplex
Equipment type:	AN/FRC-162	TSEC/CY-104
Applicable components:	Power Control Panel	Patch Panel
	Transceiver Assembly (2 ea)	TSEC/HY-12
	Jackfield Assembly	TSEC/HN-74
	Ancillary Card Gage Assy.	TSEC/KG-34

Both equipment types are part of separate functional elements, as shown, and are representative of current DEB equipments.

Table 2-3 lists the outside dimensions, weight, and power consumption by equipment type within a functional element for the current and future DEB equipment for which data were available. Dimensions and weights for the individual components were not available, although some estimates of dimensions were made by measuring photographs of the equipment. An examination of Table 2-3, in conjunction with TM 11-490-4, indicates that all items of equipment are mounted on 19-inch racks, most of which are then enclosed in equipment cabinets. With three exceptions, the dimensions of these cabinets are within the following limits: 66 inches, height x 24 inches, width x 31 inches, depth. The cabinet heights for the T1 Patch and Test Bay and the PSG (power supply group) both exceed 66 inches. However, both of these cabinets contain several blank panels, and the dimensions in Table 2-3 plus several photograph measurements indicate that all items of DEB equipment listed in Table 2-3, including those two equipment groups, could be configured into equipment cabinets compatible with MIL-STD-189 dimensions for a cabinet of 55-21/32 inches in height. The third exception, the DRAMA radio, is configured to be mounted in a single cabinet 84 inches high. However, discussions with Government and contractor personnel working on the DRAMA program have indicated that the radio components could be installed in two smaller cabinets, side by side. (In DCS facilities where ceiling and doorway constraints permit, taller cabinets can be used on the pallet to increase the level of integration.)

A review of the various equipments (omitting the power supply group) indicated that none of them consume more than 700 watts (see Table 2-3), nor are they equipped with blowers for dissipating heat. Environmental specifications for the DEB equipment are as follows:

a. Temperature: +30° to +120°F (-1° to +49°C)

b. Relative Humidity: 0 to 90% at 100°F.

From the data available, it appears that DEB equipment will operate in environments that are controlled for the reasonable comfort of attending personnel, and that individual and augmented cooling of the equipment listed in Table 2-3 and as noted is not required. The open design of the pallet, with its many cable routing openings, enables use of the subfloor space as a room air supply plenum, and permits forced-air cooling if desired. Advanced pallet concepts for application in the 1990s time frame could lead to considerably larger pallets, in which case a built-in air distribution capability could be advantageous.

TABLE 2-3. FKV/DEB C-E EQUIPMENT CHARACTERISTICS

Nomenclature	Overall Cabinet Dimensions and Weight				Actual Equipment Dimensions Weight, and Power Consumption				
	H (in.)	W (in.)	D (in.)	Weight (lb)	H (in.)	W(1) (in.)	D (in.)	Weight (lb)	Power (W)
RF Equipments									
AN/FRC-170 (DRAMA)	84	21	26	<350	74	19	25	265	-
AN/FRC-162	66	24	26	455	45	19	-	-	300
AN/FRC-165									
Cabinet 1A	66	24	26	455	45	19	-	-	300
Cabinet 2A	66	24	26	395	43	19	-	-	700(2)
1st Level Multiplex									
CY-104/104A	48	23	-	-	36	19	-	<200	<200
AN/FCC-98 (TD-1192)	23	19	-	-	19.3	19	20	<100	-
2nd Level Multiplex									
AN/FCC-97	-	-	-	-	39	19	12	105	220
TD-1193	-	-	-	-	24	19	20	<100	<300
Ancillary Equipments									
Wideband Digital Patch Panel (WDPP)	69	24	-	-	50	19	7	-	-
T1 Patch and Test Bay & TMDE	66	24	20	-	36	19	6	<200	<300(3)
T1WB1 Wideband Data Terminal	5	19	12	24	5	19	12	24	50
Alarm Monitor Group									
Transmitter	66	23.2	31	<190	22	19	-	-	10
Receiver	66	23.2	31	<262	44	19	-	-	10
Power Supply Group	76	23.25	31	944.7	-	19	-	-	160 amps (max)

(1) All equipments can be mounted on a standard 19 in. rack
(2) Includes optional AC power supply
(3) Space, weight, and power for TMDE was estimated

It must be noted that data on the power consumption and cooling requirements for the DEB 1 kW and 10 kW tropo radio systems were not available. However, forced air cooling of the final amplifier, again in an environment controlled for personnel comfort, should be adequate for the 1 kW system. The 10 kW system may be expected to require special cooling provisions.

Using Melibokus, Vaihingen, and Frankfurt as the selected representative sites, and the site equipment descriptions in TM 11-490-4, the quantities of functional digital C-E equipments currently at these sites were determined and are listed in Table 2-4. These equipments represent an initial step which has been taken in the transition of the DCS from an analog to a digital system. This step was accomplished as a part of the FKV I and II upgrade program. It is expected to be repeated across the worldwide DCS, following the DEB I, II, III, and IV upgrades in progress according to the DEB MEP. The fact that the FKV and DEB sites typically employ LOS transmission does not rule out basic similarity with the other sites when other transmission systems are considered for analog-digital upgrades. The front end (RF) equipments will be different, but the associated MUX and other units will very likely be the same (or later models) as those in FKV/DEB.

TABLE 2-4. DIGITAL C-E EQUIPMENTS INSTALLED AT THREE DCS SITES*
(FKV Phase I and II Upgrades)

Digital C-E Equipments Nomenclature	Quantity of Digital C-E Equipments Onsite at:		
	Melibokus	Vaihingen	Frankfurt
RF Equipment			
AN/FRC-165		1	
AN/FRC-162	3	1	1
1st Level Multiplex			
CY-104		12	8
2nd Level Multiplex			
AN/FCC-97	3	2	1
Ancillary Equipments			
Wideband Digital Patch Panel (WDPP)	1	1	1
T1WB1 Wideband Data Terminal		1	1
Alarm Monitor Group			
Transmitter	1	1	1
Receiver	1	1	1
Power Supply Group**	1	1	1

*Data Source: TM 11-490-4
**Requirement Assumed, in the absence of data

For preliminary configuration assessments, it was assumed that each nomenclatured equipment, mounted in one or more racks of less than 57 inches in height, would constitute a functional grouping of C-E equipment components.

2.3.1.3 Definition of Candidate DEB Equipment Modules

Limiting dimensions and weights for P/M modules are listed in Table 2-5. These values were derived from analyses of transportation modes and constraints (see Section 2.3.7), vans and shelters (Section 2.3.8.2), and DEB C-E equipment (Section 2.3.1.2). The values represent maximum pallet sizes and weights allowed to provide flexibility in the selection of transportation modes. The table also shows the inside

TABLE 2-5. LIMITING DIMENSIONS AND WEIGHTS FOR P/M MODULES

	H	W	L	Limiting Considerations
PART 1: DIMENSIONS (inches)				
1. Maximum Pallet Size (Transport)	78	84	222	Internal carriage on CH-47 B/C; CH-54 A/B
2. Inside ISO Shelter, Rigid Wall	85	88	227	ANSI/ISO Specifications
3. Inside Truck/Van/Semi-Trailer	72	76	196	M291A2; M292; M313
4. Equipment Cabinet Size	<66	24	31 (Depth)	FKV/DEB Cabinet Sizes
PART 2: WEIGHT (lbs)				
5. Maximum Pallet Weight (Transport)		10,000		LARC-V (U.S. Army)
6. Maximum ISO Shelter Payload		10,000		ISO-1-C Shelter (All)
7. Maximum Truck/Van/Semi Payload		5,000		M292; M820*
PART 3: SHELTER/VAN ACCESS CONSTRAINT (inches)				
8. ISO Shelter Door Size	69	60		ISO-1-C Shelter, Rigid (JOCOTAS)
9. ISO Shelter Removable Wall Opening	85		227	ISO-1-C Shelter, Expandable (JOCOTAS)
10. Truck/Van/Semi-Trailer Door Size	72	48		(Nominal Standard)

*Listed truck vans represent smallest payload capabilities; see Section 3.8.2 for other vehicles and payloads.

dimensions and carrying capability (weight) for the standard ISO shelter, which does not add further constraints to the maximum pallet size. For C-E equipment, the table shows the maximum equipment cabinet size (inside height is indicated) required to house the modules that make up the DEB C-E equipment types in their present configurations. The actual weight for any single rack of equipment (from Table 2-3) would not exceed 1000 pounds, and in most cases would be less than 500 pounds, both well under any of the limitations shown in Table 2-5. Finally, the table shows the most stringent ISO shelter access constraints, i.e., the door size for shelters that do not have one or two removable sides.

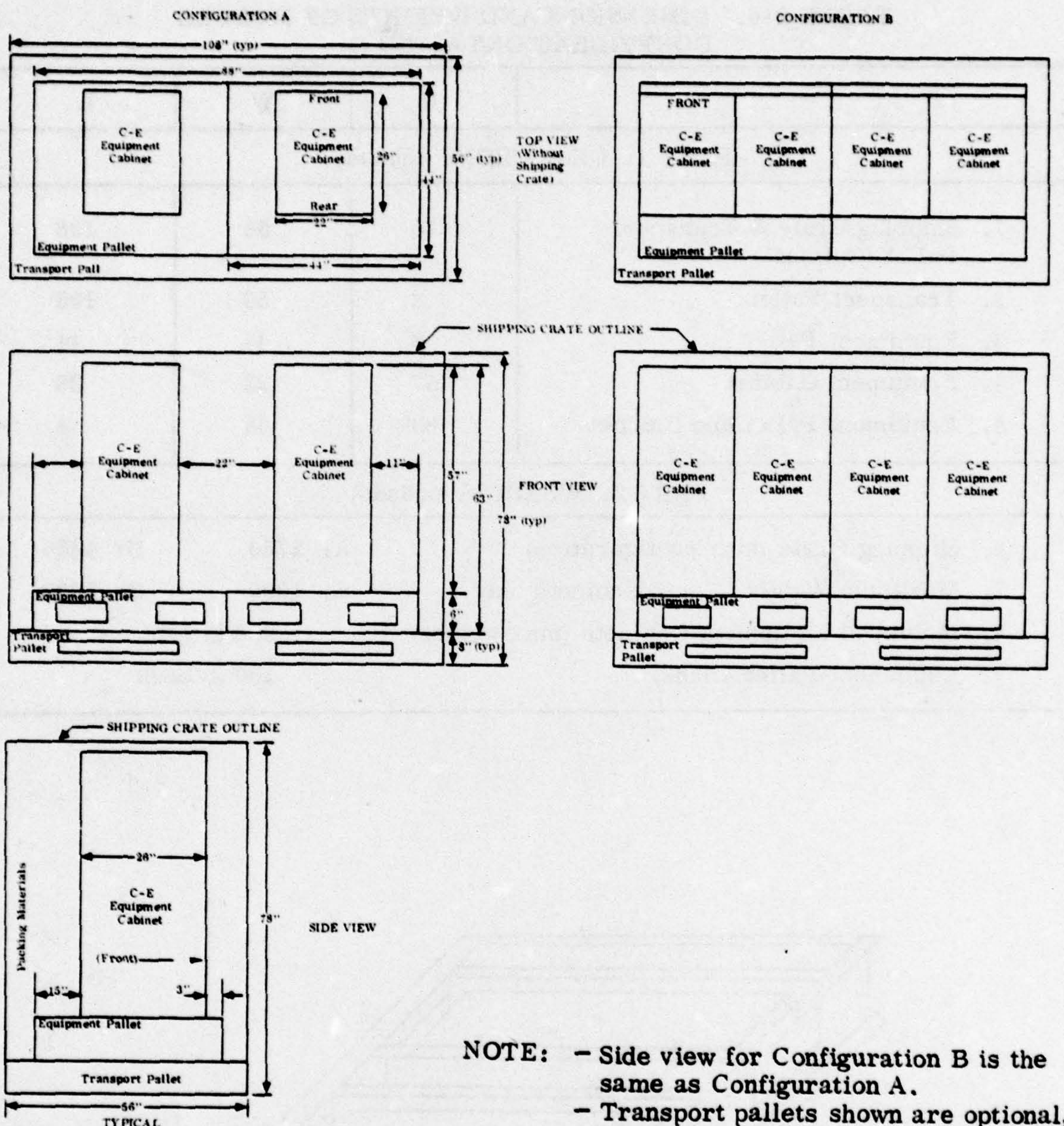
Several factors are not reflected in Table 2-5. No solid data were located regarding the actual equipment height of the power supply group. Scaling of pictures of the unit would indicate heights ranging from 55 to 66 inches, excluding blank panels. However, these measurements cannot be regarded as accurate, and no firm conclusions are drawn in this study based on the PSG unit size. No data currently on hand indicate any difficulty mounting the PSG in two adjacent cabinets if necessary. In addition, no definitive data could be obtained to define minimum DCS building doorway sizes through which modules must pass. It was therefore assumed that each site would have at least a double door for equipment ingress, and that such doorways would provide openings of at least 60 inches wide by 80 inches high (measured from industrial double-doors). Such a doorway is less restrictive than those shown for trucks, vans, or shelters in Table 2-5.

The data in Table 2-5 show that the FKV/DEB required DCS equipment cabinet size and loading fall well within the limits imposed by trucks, vans, or shelters. Therefore the next step in examining the feasibility of the P/M concept was the development of representative pallet(s) for supporting DCS equipments. It was considered that the maximum allowable module size, as depicted in the table, would be difficult to handle at most sites, and therefore did not meet the criteria of improved mobility/flexibility. Because of the anticipated handling limitations at remote sites and the need to provide maximum mobility/flexibility, the preliminary conclusion was that the actual module should be movable by no more than two individuals across a paved, level surface, and that each pallet should thus contain no more than two equipment cabinets. It was recognized that transportation handling at break-points could be compounded and bulk shipping economies attenuated due to these necessary operational criteria.

Initially, to meet the mobility/flexibility criteria discussed above, and to reduce the actual number of items that would be handled at transportation break-points, two module configurations for the DEB C-E equipments were developed. These configurations, designated A and B, are shown in Figure 2-5. Table 2-6 provides relevant dimension and weight data, and Figure 2-6 provides additional information on the equipment pallet. Both configurations are discussed below. The same equipment pallet blank is used for either configuration.

Configuration A illustrates an optional transportation pallet, two equipment pallets, and two equipment cabinets. The configuration has the following characteristics:

a. If the transhipment agency, e.g., Sharpe or Cumberland Army Depot, deems it necessary to crate the P/M module, the transportation pallet serves as the base of the crate. If it is decided to use the 463-L pallet to carry the P/M module for airlift shipment, the 473-L pallet serves as the transportation pallet, and crating is not required (special web harnesses secure the P/M modules to the 463-L pallet).



NOTE: – Side view for Configuration B is the same as Configuration A.
– Transport pallets shown are optional, at the discretion of the shipping depot.

Figure 2-5. Candidate Module Configurations

TABLE 2-6. DIMENSIONS AND WEIGHTS OF MODULE CONFIGURATIONS A AND B

	H	W	L
PART 1: DIMENSIONS (inches)			
1. Shipping Crate & Transport Pallet (Optional)	78	56	108
2. Transport Pallet	8	56	108
3. Equipment Pallet	6	44	44
4. Equipment Cabinet	57	22	26
5. Equipment Pallet and Cabinet	63	44	44
PART 2: WEIGHTS (pounds)			
6. Shipping Crate (max configuration)		A: 2750	B: 4650
7. Maximum Weight, Equip Cabinets only		A: 1900	B: 3800
8. Individual Equipment Cabinets (max weight)		950 lb each	
9. Equipment Pallet (blank)		100 lb each	

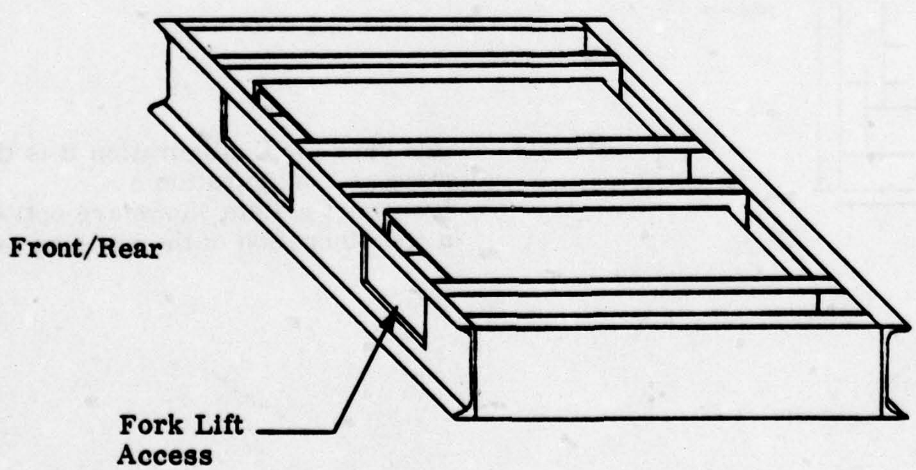


Figure 2-6. Candidate Pallet Blank

b. Each equipment pallet would provide sufficient strength to support two equipment cabinets. These pallets have forklift access structures (front and rear) which, after emplacement at the DCS site, may provide cable troughs, with openings to the troughs from the top and sides. The equipment pallets serve a number of functions – providing a common ground for the equipment, providing routing and protection for cable runs, and improving equipment mobility, e.g., by use of dollys or allowing forklift carriage, etc.

c. One equipment cabinet is mounted on each equipment pallet in Configuration A. This offers substantial flexibility of site configuration and the ability to remove individual functional items for replacement, redeployment, etc.

Configuration B illustrates an optional transportation pallet, two equipment pallets, and four equipment cabinets, with the following characteristics:

a. The transportation and equipment pallets for Configuration B are identical to Configuration A, as discussed above.

b. Two equipment cabinets are mounted on each equipment pallet in Configuration B. Equipment in the two cabinets on each pallet can be interconnected at the factory prior to shipment. This permits a higher level of station assembly prior to deployment and fewer items to be handled during shipment and site installation.

In both Configuration A and B, the height of the equipment cabinet is shown as 57 inches. The actual outside height of the equipment cabinet is expected to provide an overall panel height opening of 52-21/32 inches, and so will conform to MIL-STD-189 (Military Standard: Racks, Electrical Equipment, 19 Inch and Associated Panels). It was concluded in Section 2.3.1.2 that the 57-inch cabinet height would not impose any unacceptable restrictions on housing DEB equipments. The nearest commercially available cabinet is 58-1/2 inches in height. When necessary or as required for unique modules of equipment, additional pallets and cabinets could be used. For example, the PSG, the precise height of which was not determined, would fit easily in two 57-inch cabinets on a Configuration B module if a single 57-inch cabinet were insufficient. Higher cabinets can be used where facilities permit.

From the foregoing discussion, and assessments of the available data, there are no known or anticipated factors that would prevent the application of the P/M concept to the DEB upgrade. Some interface requirements could change (e.g., length of interconnecting cables), and redistribution of the various components in an equipment type might be required for better module interconnectivity. However, these problems should not be difficult to resolve.

2.3.1.4 Example Site Palletization

The candidate pallet and module configurations were applied to the three selected FKV/DEB sites identified in Section 2.3.1.1. While it is recognized that the equipment currently installed at those sites will not be removed and palletized, the consideration of P/M applications to those equipments is believed to be representative of what could be accomplished at a variety of DCS sites. Thus, if a wide range of sites were to be upgraded with equipment similar to advanced current DEB equipment, the P/M applicability would be similar to that described below.

Table 2-4 shows the quantities of digital equipments now in place at Melibokus, Vaihingen, and Frankfurt. Figures 2-7, 2-8, and 2-9 show potential configurations for those equipments as deployed on pallets at their respective sites. The figures assume that the power supply equipment would fit into a single cabinet. If the power supply were too large for that, the single rack would be replaced with two racks in a Configuration B module.

The signal connections between pallets, provided by field crews after the pallets are in place at the site, are generally provided by one or a few cables mating to standard connectors in the equipment racks. The more extensive intermodule interconnects required generally occur between MUX units and patch panels mounted in separate modules, typically requiring up to eight interconnect cables per MUX unit. In the module configurations of Figures 2-7, 2-8, and 2-9, MUX units have been located in the same module (for factory assembly) or adjacent modules (to minimize field site cable runs) with patch panels. The twisted-pair interconnects from MUX units to distribution frames have been indicated in the figures with footnotes. For the sake of simplicity in the figures, cables for power, grounding, etc., are not shown. As the figures demonstrate, all of the current digital DCS equipment at the three example sites can be packaged and deployed using the P/M concept, with less onsite assembly than if equipment components were shipped separately.

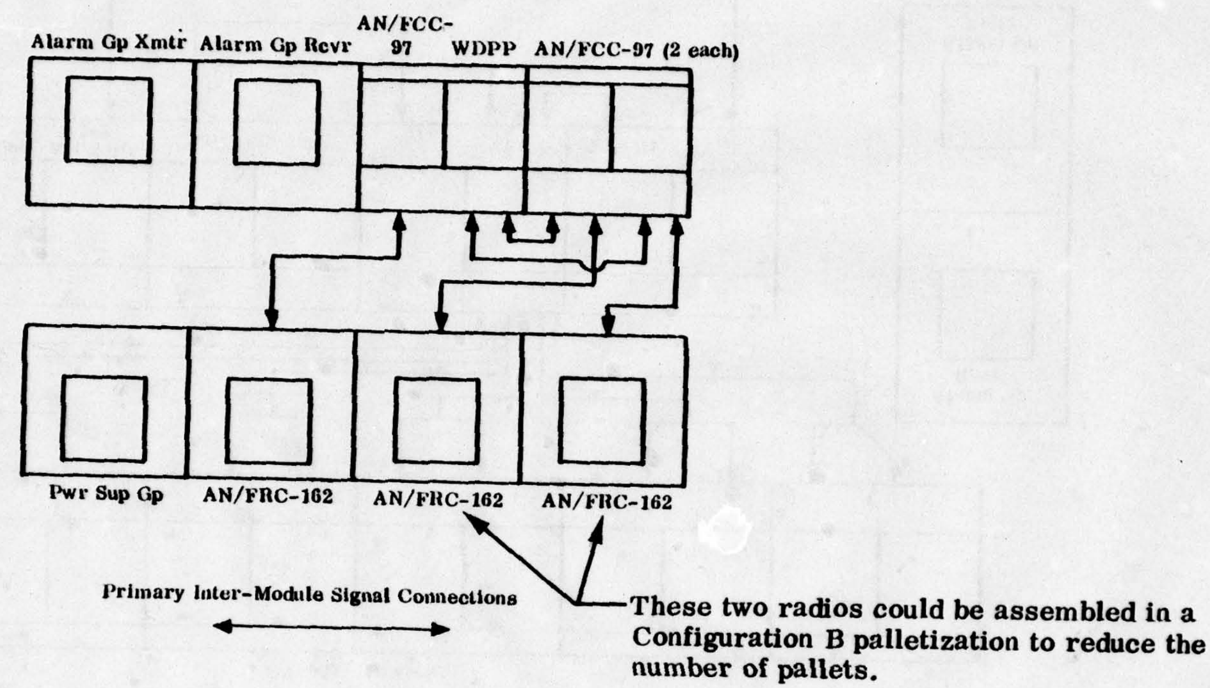
Table 2-7 shows the future equipment upgrades planned for the three example sites through the 1986 time frame. These data are extracted from the Management/Engineering Plan for the DEB. While much of the new equipment planned for installation is of the sa me nomenclature/design as the current equipments of Table 2-4, at least one set of DRAMA radio and MUX equipment is scheduled for deployment, at Frankfurt.

Figures 2-10, 2-11, and 2-12 show proposed palletized configurations of the planned equipments of Table 2-7, at their respective sites. As with the diagrams of the current equipments, only the primary signal interconnections are shown. Also as with the current equipments, Figures 2-10 through 2-12 show that all of the C-E equipments planned for the three example sites in the 1980s can be packaged, shipped, and installed in P/M form.

2.3.1.5 Probable Scope of Applicability

The probable scope of applicability of the P/M concept to the entire DCS has been assessed in two ways. First, the functions which were modularized for the existing FKV/DEB configurations were identified and counted throughout the entire existing DCS, worldwide. This resulted in a quantitative assessment of the proportions of the current system that could have been palletized if the P/M concept had already been implemented. Second, the specific equipments planned through the 1986 time period for the DEB upgrade were enumerated. This provided a total count of the equipment items that could be palletized for that major DCS upgrade program. In addition, the potential future scope of P/M applicability DCS-wide was considered, assuming for the assessment that all DCS stations would be converted from analog to digital at some point for the future DCS (see DCAC 14-75).

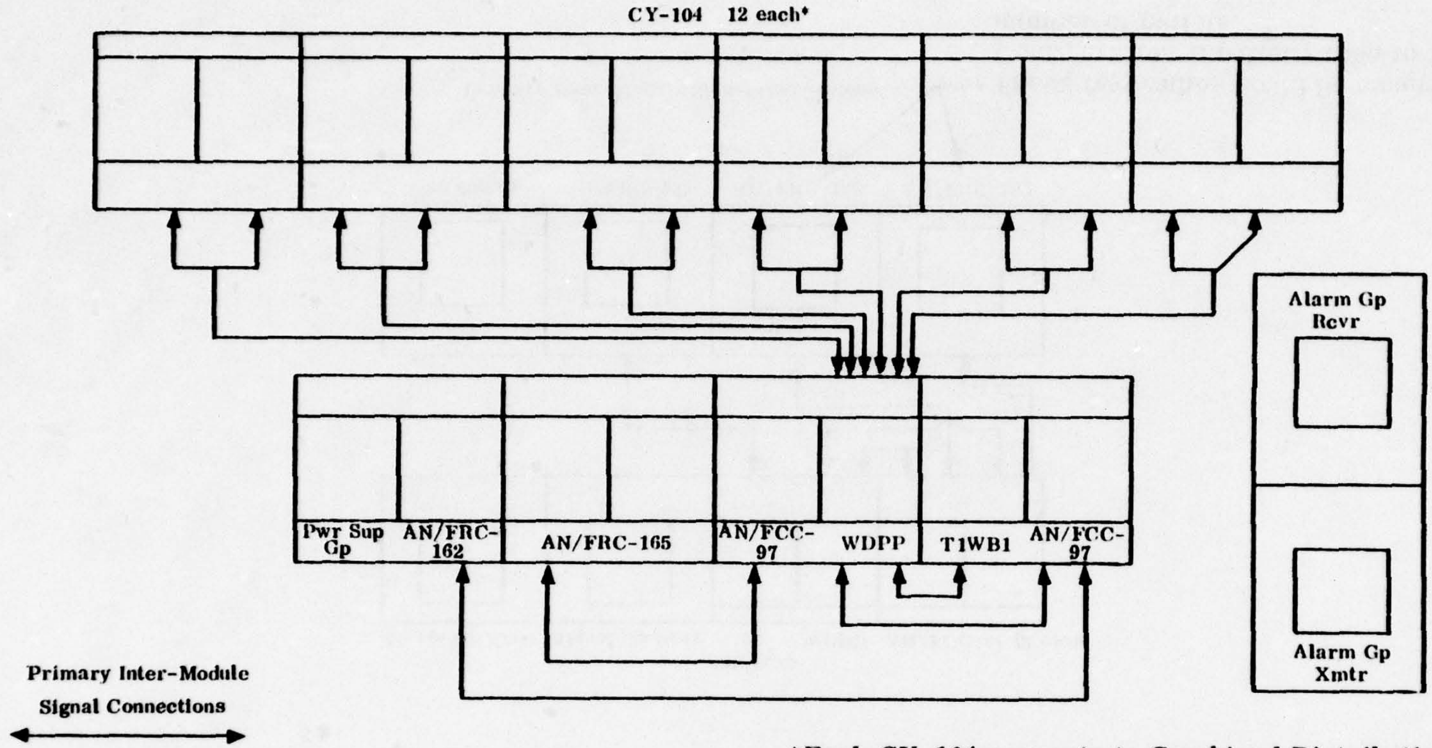
No. of Transport Pallets, if used: 4
No. of Equipment Modules Required: 6A + 2B (8 total)



Data Source: TM 11-490-4

Figure 2-7. Module Configuration and Primary Signal Connections — Melibokus (FKV II)

No. of Transport Pallets, If used: 6
No. of Equipment Modules Required: 2A + 10B (12 total)

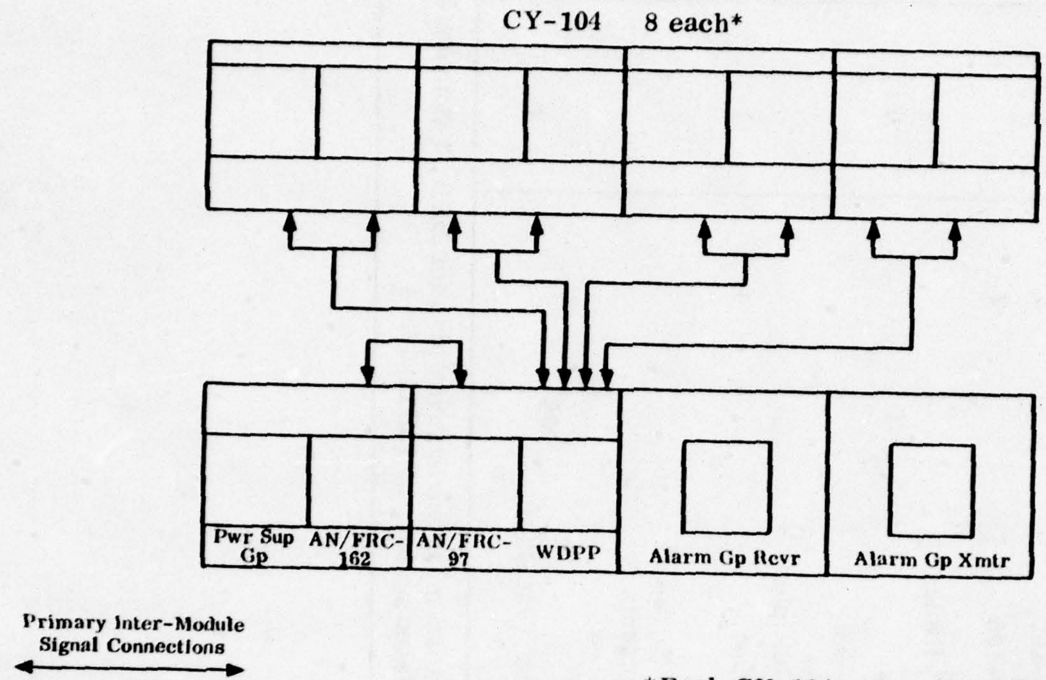


*Each CY-104 connects to Combined Distribution Frame.

Data Source: TM 11-490-4

Figure 2-8. Module Configuration and Primary Signal Connections — Vaihingen (FKV I)

No. of Transport Pallets, if used: 4
No. of Equipment Modules Required: 2A + 6B (8 total)



*Each CY-104 connects to Combined Distribution Frame.

Data Source: TM 11-490-4

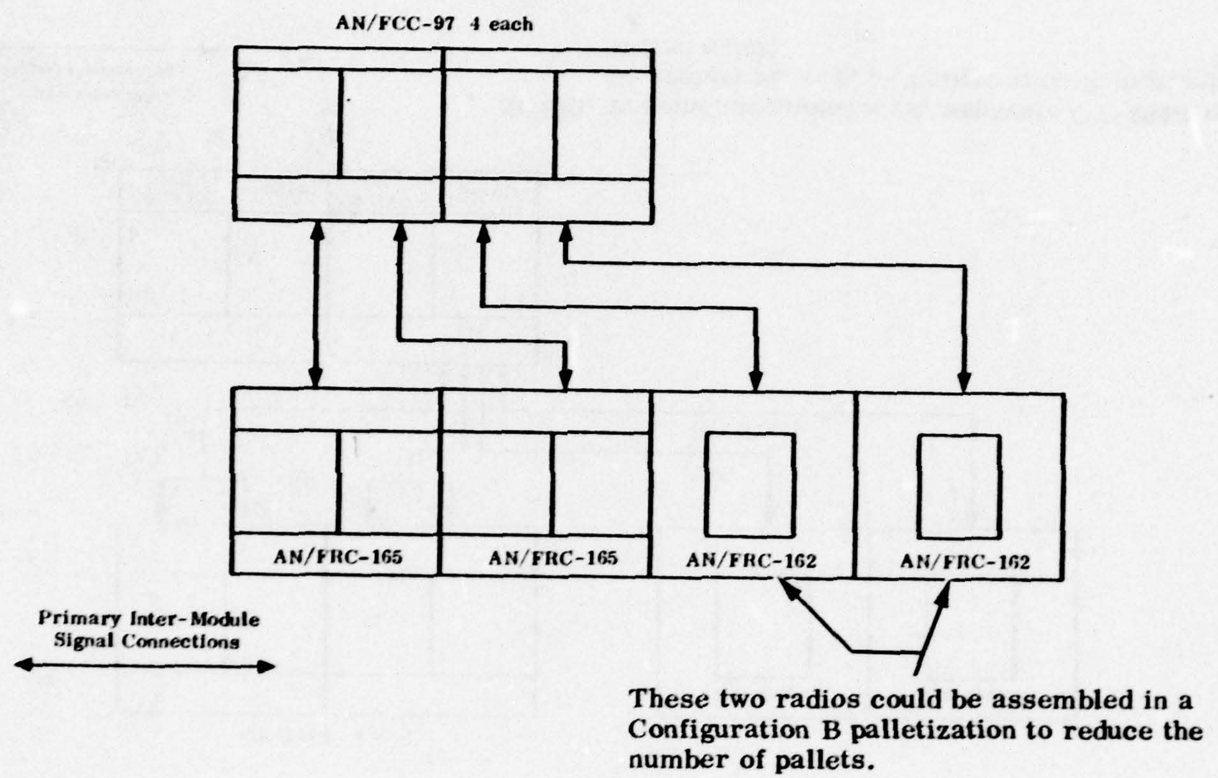
Figure 2-9. Module Configuration and Primary Signal Connections — Frankfurt (FKV II)

TABLE 2-7. DIGITAL C-E EQUIPMENTS PLANNED AT 3 DCS SITES*
(DEB I and IV)

Digital C-E Equipment Nomenclature	Quantity of Digital C-E Equipments Required		
	Melibokus	Vaihingen	Frankfurt
RF Equipment			
AN/FRC-170			1
AN/FRC-162	2	1	1
AN/FRC-165	2		
1st Level Multiplex			
CY-104A		6	8
AN/FCC-98			15
2nd Level Multiplex			
AN/FCC-97	4	1	1
TD-1193			2
Other Equipments			
Walburn			2
T1 Patch and Test Bay (TPTB)**		1	1

*Data source: Management/engineering plan for DEB, 5 October 1978
**Rqmt assumed based on data in TM 11-490-4

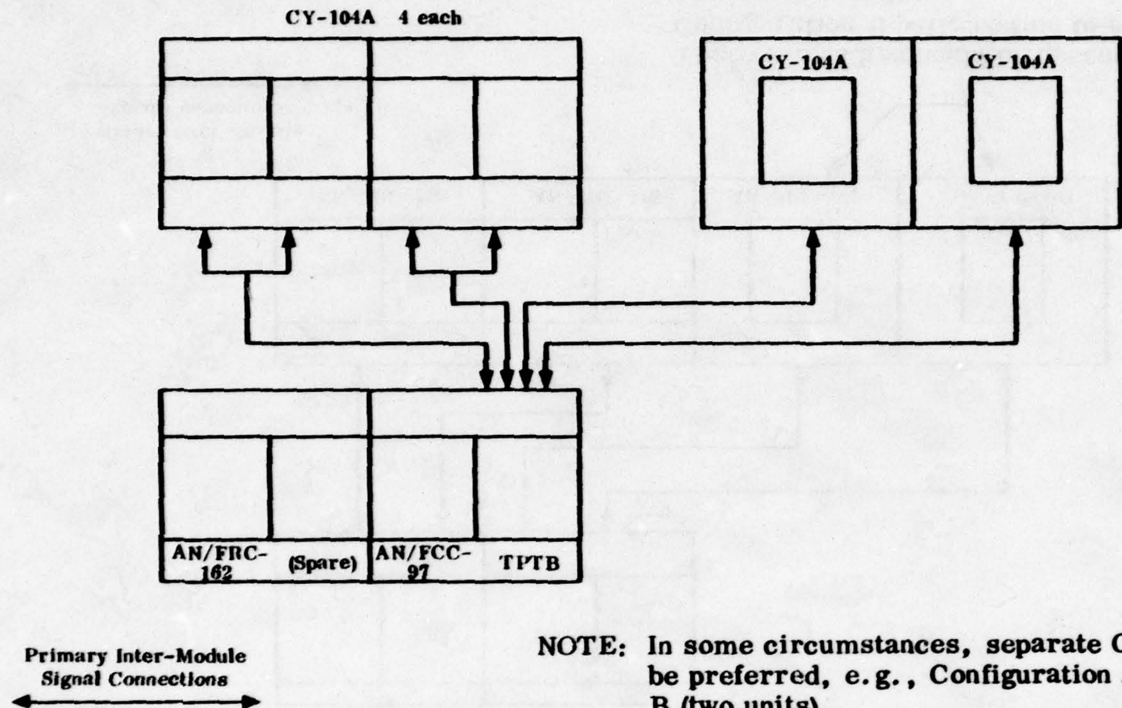
No. of Transport Pallets, if used: 3
No. of Equipment Modules Required: 2A + 4B (6 total)



Data Source: MEP for DEB

Figure 2-10. Module Configuration and Primary Signal Connections — Melibokus (DEB IV)

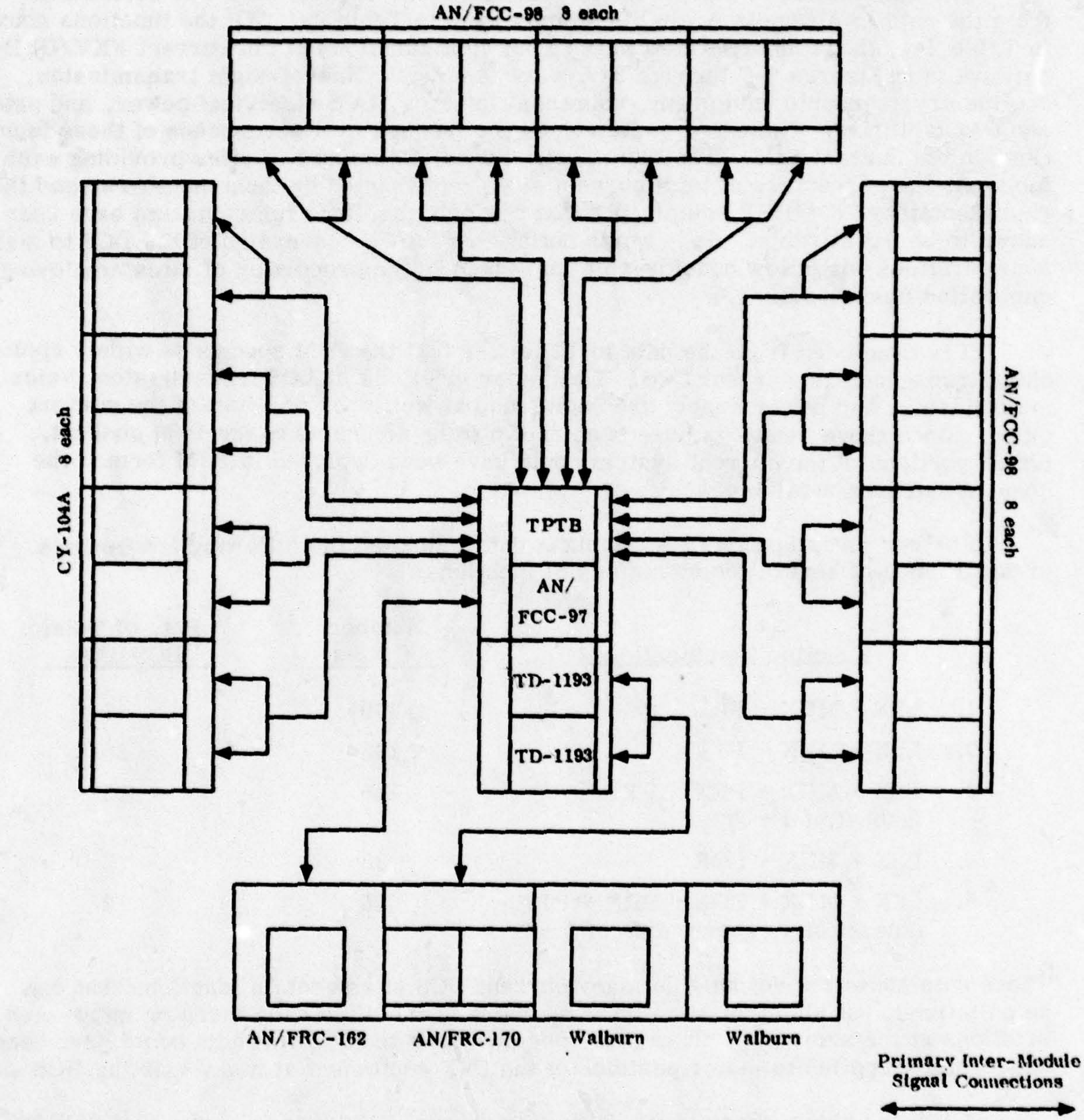
No. of Transport Pallets, if used: 3
No. of Equipment Modules Required: 2A + 4B (6 total)



NOTE: In some circumstances, separate CY-104A modules may be preferred, e.g., Configuration A (one unit) versus B (two units).

Data Source: MEP for DEB

Figure 2-11. Module Configuration and Primary Signal Connections — Vaihingen (DEB I)



No. of Transport Pallets, if used: 9
No. of Equipment Modules Required: 3A + 15B
(18 total)

Data Source: MEP for DEB

Figure 2-12. Module Configuration and Primary Signal Connections — Frankfurt (DEB IV)

The distribution of site functions throughout the current DCS was determined from the data in Appendix A, and is summarized in Table 2-1. Of the functions shown in Table 2-1, those incorporated in the P/M configurations of the current FKV/DEB network (see Figures 2-7 through 2-9) were land radio line-of-sight transmission, on-line cryptographic equipment, voice multiplexing, DCS electrical power, and patch and test facilities. Table 2-8 summarizes the frequency of occurrence of these functions in the current DCS. The table shows the total numbers of sites providing each function, the percentage of total current sites represented by those numbers, and the representative FKV/DEB equipments that perform the same functions and have been shown to be palletizable. (It is worth noting that future conversion of the DCS to digital configurations will allow considerable increases in the proportion of sites employing encryption functions.)

It is concluded from the data in Table 2-8 that the P/M concept is widely applicable throughout the current DCS. The major functions of LOS transmission, voice multiplexing, and power supply are each found at well over one-half of the current sites. Since these functions have been shown to be amenable to the P/M concept, major portions of the current system could have been deployed in P/M form if the concept had been available.

Further investigation of Appendix A data indicated the following frequencies of occurrence of several combinations of functions:

	Function Combination	Number of Sites	Pct. of Total DCS Sites
1.	LSX + MUX + PRX	269	46
2.	LSX + MUX + PTF	163	28
3.	LSX + MUX + PRX + PTF (subset of 1 + 2)	148	25
4.	LSX + MUX + BOR	38	7
5.	LSX + MUX + BOR + PRX + PTF (subset of 4, above; also of 1 + 2)	15	3

These data show that not only do many current DCS sites contain functions that can be palletized, but also that significant numbers of the sites have three or more such functions at the same site. It is thus concluded that the P/M concept could have been successfully applied to major portions of the C-E equipment at many existing DCS sites.

All of the above conclusions regarding existing DCS sites assume that facility constraints at the existing sites would not prevent the application of the P/M concept. No definitive data were obtained during the study to establish facility characteristics. It appears reasonable to assume, however, that the extensive use of equipment racks of 57-inch height indicates an ability to move objects approximating the candidate module size into current DCS sites. Further, such factors as total floor loading, power requirement, cooling requirement, and other environmental controls for a palletized installation should not be substantially greater than for current installed equipments, and are likely to be less due to increasing applications of solid state technology.

TABLE 2-8. OCCURRENCE OF PALLETIZABLE FUNCTIONS THROUGHOUT CURRENT DCS

	Function Code	Number of DCS Sites so Equipped	% of Total DCS Sites	Comparable FKV/ DEB Equipments
Transmission Medium				
• Line-of-sight radio, land	LSX	373	64	AN/FRC-162 AN/FRC-165
Support Facilities				
• Crypto (on-line)	BOR	123	21	CY-104, -104A
• Voice multiplex	MUX	399	69	CY-104, -104A
• DCS electrical power	PRX	447	77	Power Supply Group
• Patch and Test facility	PTF	248	43	WDPP, TPTB

Floor space for the modules and personnel access around the modules is also a concern at facilities. The equipment pallet requires more floor space than the equipment cabinet would alone. Further, because the 57-inch height of the equipment cabinet may require two cabinets for some equipments (PSG, FRC-170, etc.), more cabinets may be required to meet the mission. The space requirements – area of the equipment pallet versus that of the equipment cabinet(s) for the two-pallet configurations – are as follows:

	Floor Space Required, sq in	
Pallet Configuration	Equipment Cabinet	Equipment Pallet
A	682	1936
B	1364	1936

It is worth noting that existing equipment bays of side-by-side cabinets can be duplicated by Pallet Configuration B (two-cabinet) modules without increasing the length of the bay.

Since ARINC Research was not provided data describing the physical dimensions of the individual DCS site facilities, the impact that the additional floor space requirements would have could not be determined. However, since current floor plans for FKV/DEB sites show ample aisle space in front of and behind equipment bays, the increased depth dimension of the pallets (44 inches) versus that of existing cabinets (31 inches) is not expected to contribute to the space requirements. For example, the pallet area behind the cabinet will be covered over with the raised flooring to become added aisle walkway. The only contributing factor is that more cabinets may be needed due to height restrictions (a factor for only a few equipment types), assuming use of Configuration B modules.

Operator or maintenance access to equipments is not significantly hindered by the module configuration. The equipment rack fronts are located within 3 inches of the pallet edge, allowing free approach to the equipment controls and status monitoring instruments.

Another floor space requirement relates to the need for an uninterruptable power supply (UPS) at DCS sites. Specific requirements for UPS provisions at all DCS sites were not quantified for this study. However, all of the DEB sites require a UPS, per the MEP, so that it is assumed all DCS sites require one. The actual UPS electronic modules can be palletized. The problem arises at those sites using a number of DC batteries that provide backup power to the C-E equipment. The number of batteries required is dependent upon the type of site (remote or manned) and the equipment power consumption requirements. Battery packs could be configured and palletized for fixed C-E sites, but this could add to the potential floor space problems. Pallets could not be densely loaded with batteries without exceeding the pallet weight constraints established earlier. Palletizing batteries for mobile shelters also adds ventilation problems, which might require the use of an additional shelter to house the batteries. These and other related considerations were outside the scope of this study.

While the FKV/DEB equipment investigated does not encompass all of the functions shown in Appendix A and Table 2-1, it is felt that the candidate pallet configuration presented was demonstrated to be highly flexible in accommodating various

equipments. With the option of the A or B configuration for modules, a total of approximately 114 inches of vertical rack space (two commercial cabinets of 57 inches internal height each) can be provided on each pallet. While specific size data were not available for all DCS C-E equipments, qualitative information received, as well as that obtained on visits to several DCS sites, indicate that most DCS functional equipment sets are comprised of one or more rack-mountable units similar in size and weight to the FKV/DEB equipments (see Table 2-3). It therefore appears that the majority of current DCS equipments could be mounted in palletized racks. The possible exception to this conclusion is the family of equipments listed in Table 2-1 under "Traffic Switches". Those systems tend to be large and unwieldy, and require extensive interconnection among modules. Thus, a pallet/module configuration allowing significant levels of factory assembly of those equipments would tend to be much larger than allowed by the criteria established in Section 2.3.1.3.

Consideration of distribution frames as candidates for palletization and modularization was not pursued for a number of reasons. Typically, distribution frames are large metal frameworks to support various panels that facilitate the electrical patching and interconnecting of great numbers of communication paths or channels. As such, they represent a bulky item of relatively small cost (as compared to C-E solid state equipments) that is customized for its specific site, i.e., the interconnections in the frame are manually assembled and frequently changed as necessary to meet local routing, re-routing, and monitoring/test requirements. Thus, a standard distribution frame from central depot supply would begin to reflect its site's changing requirements from day one, and in several months would be so uniquely patched that the man-hour costs of restoring it to standard form for possible re-use at another site could exceed its salvage value.

The rapid evolution of solid state processor (software) controlled electronic switching systems, e.g., RCA's Electronic Private Automatic Branch Exchange, EPABX, equipments, suggests that distribution frames may be replaced by a related equipment development to eliminate manual patching and interconnecting access requirements. The solid-state replacement equipment would be a much more suitable candidate for palletizing and interchangeable use across the DCS network

Support equipment required at the existing FKV/DEB sites has not been defined during this study. However, discussions with personnel currently or previously working with the DCS have indicated that no unusually large or complex support items are required. Engineering experience and reviews of equipment catalogs also indicate that most test equipment items are available in directly rack-mountable form or in a size that would fit onto a shelf installed in a standard 19-inch rack structure. Such units could be assembled or mounted into palletized racks prior to shipment with no particular difficulty. Access may be required for periodic maintenance or calibration, but this will not create any problems unique to the DCS applications; the same requirements would exist and are dealt with routinely in many varied support equipment installations. It is concluded, although without quantitative substantiating data, that much of the required DCS support equipment could be assembled and mounted in Configuration A or B pallets if a relatively fixed installation at the site is desired. (Some support equipment, such as oscilloscopes and wave analyzers, may be of such broad utility at a site that a more mobile installation, such as a laboratory cart, is more desirable.)

As a general conclusion regarding applicability of the P/M concept to equipments of unknown detailed characteristics, including bins or drawers for tools or spare parts, any that can be mounted in 19-inch racks, whose external dimensions do not exceed 57"H x 22"W x 26"D to form a unit weighing less than 1,000 pounds, are potential candidates for P/M application. Such applications could be limited in individual instances by unit spacing for air circulation, specific required relative physical locations of separate units, etc. However, equipment photographs, specifications available, and installations observed at DCS sites all indicate that such constraints are the exception rather than the rule.

The distribution of planned C-E equipments for the 1980s DEB upgrade program was determined from the summary tables presented in the DEB MEP. Table 2-9 presents data extracted from that plan, and shows the total numbers of each type of equipment to be deployed in DEB Stages I through IV. Referring again to Table 2-3, it can be seen that the equipments planned in quantities greater than 20 each will all fit into the candidate pallet configurations. The only possible exception is the TSEC/CI-3, for which size and weight data were not obtained during the study. Those units for which data were obtained and which were found to be compatible with the candidate modules and to constitute 1,810 of the total 2,134 items scheduled, indicating a minimum scope of P/M applicability of 85 percent of all planned DEB upgrade C-E equipment.

Specific data showing new equipments planned for other portions of the DCS during the 1980s were not obtained during the study period. Therefore, it cannot be conclusively stated what portion of the entire future DCS the P/M concept is applicable to. If equipment upgrades to the remainder of DCS will be relatively minor during the 1980s, then the DEB upgrade represents most of the applicability of the P/M concept. If, however, significant upgrades are planned, the applicability of the P/M concept can be extrapolated from the DEB findings, at least in terms of the minimum anticipated scope as inferred by DCS-wide functional similarity to DEB. The previous results from the current DCS, which indicated that at least 46 percent of current sites have combinations of functions found in the DEB and amenable to P/M application, combined with the above conclusion that at least 85 percent of the DEB upgrade C-E equipment is suitable for palletization, leads to the conclusion that at least 39 percent of the entire DCS has a high potential for P/M application.

As in the case of the current DCS configuration, no specific data were available for either the facilities nor support equipment for the future DCS. For the new DRAMA radio and multiplex equipment, the support equipment has not yet been defined, and therefore no specific conclusions can be generated. Current electronic equipment trends toward increased use of digital designs have led to more sophisticated built-in test functions in many equipments. It is anticipated that such trends could be applied in future DCS units, reducing the need for separate onsite support equipment. Further, if the newer maintenance concepts such as manufacturer warranties and all-depot repair policies are applied to future DCS installations, the onsite maintenance activities may be reduced to remove-and-replace actions, with failed items being returned to the manufacturer or depot for repair. Such fault isolation capability may be provided entirely by built-in test in some future equipments.

The current DCS plans for the 1980s call for extensive use of existing facilities (possibly with modifications) rather than construction of new facilities. As stated earlier, no specific details regarding current facility constraints were available during this study. Likewise, no data were available regarding facility modifications.

TABLE 2-9. NEW C-E EQUIPMENT QUANTITIES FOR DEB UPGRADES THROUGH 1986

	RF Equipment					Multiplex Equipment											Walburn		Miscellaneous				
						1st Level MUX					2nd Level MUX						TSEC/CI-3						
											AN/FCC-97		TD-1193										
	AN/FRC-170	AN/FRC-162/165	MD-918	1 kW Tropo	10 kW Tropo	CY-104A	AN/FCC-98	AN/FCC-98 (3 ch)	CY-104A (Tac Interface/Restoral)	AN/FCC-98 (Tac Interface/Restoral)	4-port	8-port	2-port	4-port	6-port	8-port	T-1 Line Rate	MBS Rate	Direct Conversion Unit	Span Terminating Equipment	NRZ/Bipolar Conv. and Span Terminating Equipment	MBS Cable Interface	Total Items, All Types
DEB Stage I		36				48			5			28							8				125
DEB Stage II	26					25	160	28	8	20					4	42		46			16		375
DEB Stage III	34					1	73	36		13					8	18		32				8	223
DEB Stage IV	146	48	12		12	115	374	158	30	96		48	14	24	62	82	6	184					1,411
Total	206	84	12		12	189	607	222	43	129		76	14	24	74	142	6	262	8		16	8	2,134
Compatible with P/M Modules on basis of data	X	X				X	X	X	X	X		X	X	X	X	X							1,810
Not Compatible, on basis of data																							0
Data not available for evaluation			X		X												X	X	X		X	X	324

For purposes of assessing the scope of applicability to future DCS installations, it has been assumed that the future facilities will not impose new constraints that would impede the applicability of the P/M concept. It does not appear that the P/M concept presents any insurmountable physical interface problems. The combined pallet and cabinet height should not conflict with existing equipments or facility limitations. Cable, connector, and waveguide placements are basically compatible with current practice. A pallet with two cabinets on it can slide into place where two cabinets would fit in a conventional installation.

In addition to the fixed site applications exemplified by the FKV/DEB installations discussed above, the applicability of the P/M concept to mobile or contingency installations was investigated. As an example of such an application, the types I and II DCS reconstitution packages (as defined in the DEB MEP) were configured into palletized form. Table 2-10 lists the equipments included in each of the two packages, and Table 2-11 shows the total weights for the indicated quantities of each equipment type. For palletization, it was assumed that all equipments would be installed in B-type modules for minimum station size and maximum factory preassembly. Figure 2-13 shows how the equipments could be configured in modules and fitted into the inside of a one-side or two-side expandable 8-foot by 20-foot ISO shipping container for transport to a site. Once at the site, one or more of the shelter walls are moved out to double (or triple) the size of the shelter, so that the equipment can be operated.

TABLE 2-10. EQUIPMENTS COMPRISING DCS RECONSTITUTION PACKAGES

	Quantity of Digital C-E Equipment	
	Type I Package	Type II Package
RF Equipment		
AN/FRC-165	2	
AN/FRC-170		2
1st Level Multiplex		
AN/FCC-98		6
CY-104A	4	
2nd Level Multiplex		
AN/FCC-97	2	
TD-1193		4
*Ancillary Equipment		
Wideband Digital Patch Panel	2	
Alarm GP		
Transmitter (Xmtr)	1	
Receiver (Rcvr)	1	
Fault Alarm System (FAS)		1
Power Supply Group	1	1
T1 Patch and Test Bay		2

*Ancillary equipment is not specified in MEP. Equipment types and quantities are assumed, based on data in TM-11-490-4.

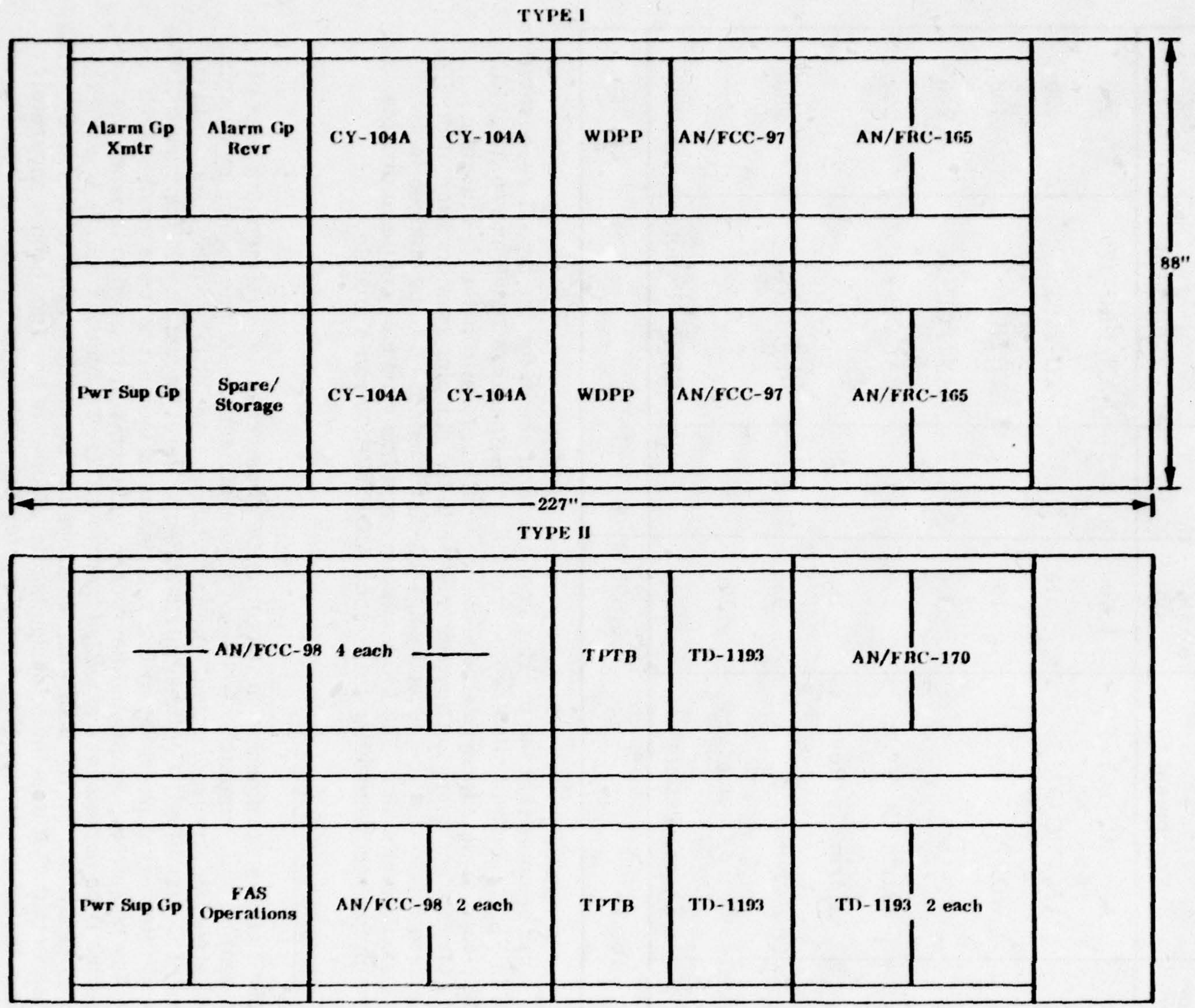
TABLE 2-11. EQUIPMENT WEIGHTS FOR DCS RECONSTITUTION PACKAGES

Type I Package			Type II Package		
Qty	Equipment	Weight (lb)	Qty	Equipment	Weight (lb)
2	AN/FRC-165	1,700	2	AN/FRC-170	950
2	AN/FCC-97	210	4	TD-1193	420
2	WDPP	150	2	TPTB	400
4	CY-104	800	6	AN/FCC-98	1,200
1	Alarm/Gp Xmtr	270	1	FAS Opns	200
1	Alarm/Gp Rcvr	190			
1	Pwr Sup Gp	950	1	Pwr Sup Gp	950
1	Spare Cabinet	100			
8	Equip. Pallets	1,200	8	Equip. Pallets	1,200
Total		5,570	Total		5,320

It must be noted that the packing configuration shown for the type II reconstitution package in Figure 2-13 is missing one module. That package requires two AN/FRC-170 units, each of which requires a separate Configuration B palletized module. There is insufficient room for another module in the shipping configuration of the ISO container shown, so that the second AN/FRC-170 would need to be shipped in a separate small container. The ISO container would be expanded onsite to provide ample room for accommodating the second AN/FRC-170 radio module.

2.3.2 Technology Survey

The Defense Documentation Center (DDC) was requested to search its files of reports dealing with communications and electronic equipment packaging, modularization, palletization, transportation, and installation. An initial search resulted in 60 citations of Unclassified, Confidential, and Secret level documents dating back to 1974. Results of this search provided so few references of interest that a second search request was prepared. Additional key words and terms were used to broaden the survey, and the time domain was extended back to 1972. The second search brought the total to 86 citations, but the additional 26 proved to be of little value to this study. The indication is that C-E equipment packaging developments have not been a separately addressed factor in military R&D programs for the past seven years, nor considered dominant enough to appear as titles of programs or as descriptive key words or terms for report retrieval in the DDC system.



NOTE: Type II requires 2 AN/FRC-170 units.

Figure 2-13. Module-Configurations for Types I and II DCS Reconstitution Packages (One- or Two-Side Expandable ANSI/ISO 8 x 8 x 20 Shelters)

In the effort to survey recent Government and commercial developments in the palletization and related fields, numerous phone contacts, 24 visits to sites organizations, and reviews of recent trade publications were carried out. (Contacts and documents are listed in the appendixes to this document.) The reviews of trade publications, from Thomas' Register of Manufacturers and Products through the many electrical-product buyers guides, directories, and master catalogs did not reveal any standard commercial electrical systems as equipment modules available from two or more manufacturers. So-called new standard system modules would offer features compatible with older common systems, but the modules themselves were not readily interchangeable. Various manufacturers offer comparable digital EPABXs, which are basically compatible with commercial telephone networks, but each has different numbers of lines, numbers of trunks, class of service options, etc. Off-the-shelf commercial C-E equipment modules continue to reflect their individual manufacturers' ideas and design features.

The phone calls and visits to individuals at sites and facilities actively engaged in military electronic equipment programs provided useful information regarding past successes and failures in attempting to develop and broadly apply standard pallets or modules, as well as specific information of new developments and trends. For example, at the Travis Aerial Port at Travis AFB, the use of the 463-L solid Type III pallet in air cargo shipments has been discontinued. The added weight of the Type III, which is twice as thick as the basic Types I and II (all 463-L designs), was considered excessive. The emphasis at CERCOM's Shelters, Facilities, and Assembly Section at Ft. Monmouth has recently shifted from pallet/module developments to custom installation designs for special or unique tactical systems applications. The organizations contacted and visited were identified by the study sponsor, USACEEIA, and by national reputation for significant accomplishments in related fields. The Proceedings of the Mobile Electronics Packaging Symposium at MITRE Corporation in November 1977 provided an overview of organizations currently involved or, interested in the communications and electronics equipment development field.

Among the more significant pertinent equipment developments noted were the TRI-TAC, the ESS-3 program, and the Hughes Satellite Ground Systems program. The TRI-TAC (AN/TTC-39) system is of modular design, such that a basic switch can provide growth capability from 120 to 600 external terminations per switch. Further, standardized form-and-fit design permits the exchange of one analog module for one digital module in the same physical space. Since the digital components will be smaller than the analog types, each digital module will accommodate many more terminations. The switch is normally installed in two transportable shelters. However, they do not include the supporting power and environmental control units. One of the more relevant considerations in the TRI-TAC program is the development of a standard rack system to accommodate the equipments for a fixed site installation. This rack design, illustrated in Figure 2-14, has some desirable features, such as lifting eyes, leveling, and casters for movement on smooth hard floors, which are applicable to the pallet approach.

Another noteworthy development is the unitization embodied in the No. 3 Electronic Switching System (ESS) by Bell Laboratories and Western Electric Company. The No. 3 ESS is the first to be so unitized. That is, the system is factory assembled, cabled, tested, packaged, shipped, and installed as one complete unit. This system has three lineups (rows) of equipment: an 8-bay lineup containing the processor and maintenance and power equipment, a 13-bay switching-network lineup, and an 8-bay switching-network lineup. The ESS is about 34 feet long, 10 feet wide, and 9 feet high, and weighs about 24,000 pounds.

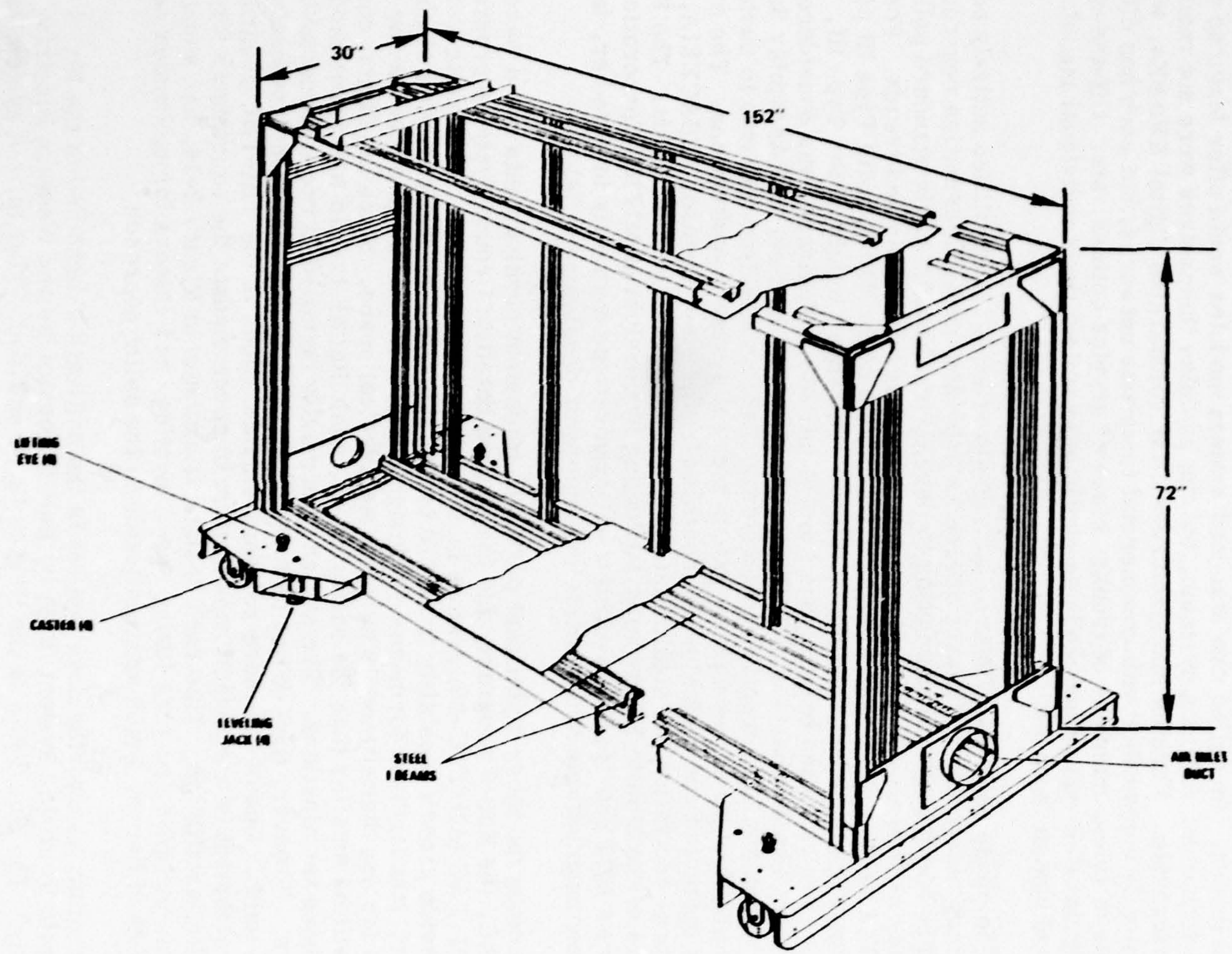


Figure 2-14. Rack System Outlines for TTC-39 Fixed Plant Installation

Other Bell Telephone switching systems, in contrast to the No. 3 ESS, employ practices similar to those now in use in the DCS, i.e., they are disassembled after being tested and their equipment frames are packed for shipment. When these systems arrive at their central office destination, they must be reassembled, recabled, and retested. Thus, work is duplicated and the extra processes present opportunities for loss, error, damage, or delay.

In deploying a No. 3 ESS after it is manufactured and tested, special shipping hardware is attached to the lineups of frames to create a single rigid structure. This structure can withstand the mechanical stresses of truck transport, making it unnecessary to house the system in another container or to mount it on a heavy steel platform. When a unitized No. 3 ESS arrives on site, the shipping hardware is removed and power and customers' lines are connected. Only pre-cutover tests have to be made at the installation site.

Western Electric Company engineers' report (Bell Laboratories Record, June 1978) that unitization greatly reduces time-consuming installation tasks: the onsite setup takes about half a day; test calls begin within 2 days; and customers' calls are switched within 8 weeks. The report further indicates that this is about a third the time and effort required for an electromechanical switching system of comparable capability. Shipping a No. 3 ESS as a complete package also prevents parts from being lost or from arriving at different times – problems that delay cutover and increase costs.

Because a unitized No. 3 ESS uses a fixed design, operating telephone companies are saved the time and expense of having Western Electric re-engineer each upgrade, i.e., *the locations of its component frames, cable racks, cables, and connectors.* A No. 3 ESS comes with its own power plant and lighting fixtures, ready to be connected.

Hughes Aircraft Company (Test Systems Department, Satellite Ground Systems Laboratory) has been successfully using pallet-mounted equipment racks for more than 10 years. The equipments involved are assembled into test control centers to support satellite vehicle launches at various sites. After use at a site for months or even years, they are separated and shipped back to the Hughes Laboratory or to other launch control sites for reassembly and use. The equipments, which include computers, microwave, telemetry, and command systems, are mounted in cabinets enclosing 19-inch racks. The racks provide front panel mounting, but the equipments are secured on shelves supported by central structure members (extruded structural forms). Each rack is enclosed in a cabinet, with provision at the front bottom for an inlet for ambient cooling air. Since most of the equipment is of off-the-shelf commercial design, it is largely solid state technology and does not require significant amounts of cooling air. The microwave (transmitter) units are specially fitted with flexible air conditioning ducts to provide the necessary heat removal.

The racks and cabinets are mounted onto aluminum I-beam pallets of various sizes, all being approximately 6 inches high. A representative pallet, roughly 5 feet by 7 feet and covered with sectioned vinyl flooring, can be picked up by two men when empty. Loaded pallets (up to 1,600 pounds) move easily on built-in ball casters across hard floors. The pallets are designed for quick bolt attachment to one another at their corners to build up control center equipment areas. The I-beam structure of the pallet has many large holes in the webs of the I-beams for ventilation and cabling routing as required. It has not been necessary to use the sub-floor space for air conditioning ducting; any special cooling needs have been met by above-floor flexible ducts to the particular cabinets, e.g., microwave transmitters.

The extensive and successful experience of Hughes with many sets of these palletized satellite ground control and test center equipments is a timely example of the feasibility and design philosophy of modular assembly to promote safe transport, rapid setup, and rapid take-down for removal and relocation. It should be noted that Hughes has relied exclusively on truck transport across CONUS for its pallet modules.

As additional examples of communication equipments that have been fielded in pre-assembled form, transportable to operational sites for rapid installation and checkout, data were gathered for the AN/MTC, the AN/TTC-28, and the AN/TYC-8(V)4. Characteristics of these equipments were extracted from the Communication-Electronics Transportable Systems Staff Planning Guide, USACC document CCP 105-6, dated 1 November 1974. The equipments do not represent the technology of C-E equipments anticipated during the 1985-1990 timeframe, nor are they mounted on simple pallets (all three are van or truck-trailer contained). However, they did demonstrate the feasibility, more than four years ago, of pre-assembling major units providing communication functions similar to those of DCS and deploying them rapidly to establish operational capabilities at remote sites.

The AN/MTC is a family (MTC-1, -7, -9) of equipments providing an automatic voice switching facility, comprising a van equipped with permanent telephone central office facilities for 100 telephone lines, trunk circuits for AUTOVON, dial PBXs, and manual ringdown circuits. Up to 200 lines may be provided through the addition of another van. The unit is contained in a 10-ton semi-trailer (XM-850), measures 477"L x 96"W x 132"H, and weighs 34,500 pounds. It is powered by a separate AN/MJQ-10 unit (168"L x 93"W x 96"H, 11,600 pounds) providing two 30-kW, 60-Hz power generators. The unit is transportable by C-5A aircraft and 5-ton tractor. Installation requires a 10-man team working for 4 hours. The availability of the unit for deployment is controlled by the JCS.

The AN/TTC-28 is a 600-line dial central office, housed in two semitrailer vans. The two vans contain the primary switching equipment and all of its associated support equipment, including attendant switchboard, combined distribution frame, air conditioning, heating, and power plants (AN/MJQ-4, dual 45-kW, 60-Hz generators). Each van measures 464"L x 98"W x 132"H and weighs 32,000 pounds. The system is air transportable by two C-130Bs or one C-5A aircraft, and is moved on land by two 5-ton tractors or two 2-1/2 ton trucks. Installation requires 72 man-hours by a skilled team. The unit is maintained in a complete state of readiness and can be deployed within 48 hours. Availability is under the control of USACC/DA.

The third unit, the AN/TYC-8(V)4, is a digital subscriber terminal providing all equipment necessary for transforming messages from punched paper tape or punched EAM cards into signals for transmission over the AUTODIN network, or converting received signals into punched card and tape form. It is housed in two semitrailer vans connected by a passageway. The communication capability includes encrypted transmission and receipt of messages (two TSEC/KG-13 units may be installed in each van). The two vans measure 412"L x 96"W x 132"H each, and weigh 29,450 and 27,050 pounds, respectively. The entire unit is transportable by a single C-5A aircraft and a 5-ton tractor. Installation requires a 7-man team working for 6 hours. The unit, under control of the JCS, is available for deployment within 24 hours.

The foregoing developments are representative of the more recent working level technology and demonstrate the feasibility of P/M-type concepts for deployment of military and/or C-E equipments. In the case of exotic and solid-state equipment palletizations used in space platforms and some military aircraft, costs are indicated to be and will likely remain unjustifiably high for DCS ground site applications because of the premium for weight reduction and high reliability requirements in extreme environments.

2.3.3 Performance Trends

Military specifications and technology practices often evolve at differing rates. A series of related technology breakthroughs can trigger rapid evolution and advances in equipment design and working practices. At such times, specifications trail the state of the art, largely because the typical time cycle for specification writeup, concurrences, and approvals runs to several years at best. Thus, by the time such new specifications are ready for promulgation, rapid advances in the state of the technology may have made them obsclete and established needs for newer specifications. When technologies mature and exhibit little change in periods of several years, specification development can catch up and exert meaningful guidance for new equipment procurements. The recent rapid advances in solid state C-E technology have displaced some tube-type technology and its related specifications. Requirements for new applicable specifications and for new considerations involved have been recognized and are being addressed by the DoD standards program.

For the development of new equipment, as well as the procurement of production models of new equipment, the DoD standards program is developing and issuing new DCS planning standards, as noted in and exemplified by MIL-STD-187-310, Switching Planning Standards for the DCS. These planning standards contain performance specifications that apply to the evolving and future DCS. Some of these specifications may reflect minimum acceptable values for interim guidance or be based on best technical judgment of what is needed for the future DCS. In general, the new DCS planning standards address overall operating features and functions of end equipments rather than all possible performance values; their objective basically is to minimize systems and equipments interface problems.

The new planning standards for the DCS are supported by DCS equipment specifications and practices as presented in the latest standards in three areas: development, engineering, and operations. These standards are:

a. Development: MIL-STD-188-100 series, Common Long Haul/Tactical Standards; MIL-STD-188-300 series, Long Haul Standards; both published by OSD.

b. Engineering: DCA CIR 330-175-1 (formerly DCA CIR-175-2A), DCS Engineering-Installation Standards, published by DCA.

c. Operations: DCA CIR 55-1, DCS Operating Standards, published by DCA.

These electrical performance standards are promulgated by DoD for use of its agencies and departments, and apply primarily to the present DCS analog equipments. They prescribe performance values that have been achievable within the state of the art and are based on measured performance of actual equipment and circuits. However,

the trend now is to use the new DCS planning standards, e.g., MIL-STD-187-300, to guide new equipment developments by controlling interface specifications, and granting more freedom to internal equipment circuit designers to reflect technology advances.

The use of palletized modules of C-E equipment is wholly in accord with this interface control trend. The electrical interfaces between equipment units assembled into modules on pallets are made and tested at the manufacturer's facility. The electrical interfaces between P/M modules and their host site/facility are accomplished by connectors, rather than by internal access wiring, effectively reducing test and measurement requirements on-site while ensuring desired performance capabilities.

As noted earlier, the evolution of digital solid state technology is approaching a degree of maturity; i.e., the differences in size and weight of the next generation DRAMA equipments as compared to the current digital equipment at the FKV/DEB I sites are minor. Consequently, specifications oriented towards equipment interface control would be generally applicable to succeeding generations of C-E equipment in the P/M modules.

The specifications for the DRAMA equipments (AN/FRC-170, TD-1192, and TD-1193) were reviewed for factors that would impact the P/M concept. In general, no features were noted that would render the concept infeasible. The equipments are being developed to mount in standard 19-inch racks compatible with the candidate module configurations developed. The current specification requirement that the radio AN/FRC-170 be mounted in a single rack is incompatible with the 57-inch height of the candidate module rack. However, discussions with cognizant design personnel have indicated that the radio could be mounted in two adjacent racks with no problem. (A specification change would be required by the manufacturer.)

DRAMA equipment connector and interconnect cable types are compatible with standard practice in digital DCS elements today, as are the data rates at interfaces. Connector locations on the equipments are generally in the rear, where ample space is available for cables. The RF connectors on the radio are located at the top of the unit, which may impact module cabinet design but should not preclude feasibility.

The equipment is designed to operate from dc or ac power sources. Protrusions from the front panels will not exceed 2 inches, so that the mounted equipments will lie within the overall maximum dimension envelope of the candidate module, on which the rack is mounted 3 inches behind the pallet front edge. Built-in test and replaceable card/module designs are required, which will be highly compatible with the DCS site operations of the future. The units are to perform properly without the use of blowers or other means of forced air cooling (Specification CCC-74049, 16 July 1976).

In general, it is concluded that the specifications for the DRAMA equipment are highly compatible with the P/M concept.

2.3.4 Constraints

The beneficial application of the P/M concept to the DCS is faced with a number of constraints, including the variety of facilities currently used as DCS sites, the variety of equipment installed at the respective military DCS sites, requirements to support new objectives cited in the DEB MEP, and the funding limitations for re-engineering facilities for commonality in accommodating P/M units. (Other more quantifiable constraints, such as transportability and facility characteristics, are discussed under separate headings elsewhere in this chapter.)

The variety of facilities in current use is not likely to change markedly over the next 10 years. Fortunately, the growth provisions at most sites are large enough to permit rearrangement of equipment bays and configurations, as indicated by the individual site details in the DCA records and DCAC 300-85-1, DCS Facility/Link Data Base (U). The newer equipment for replacing analog units will be digital and increasingly will be of solid state componentry, thus much smaller. These smaller units will have reduced need for electrical power and air conditioning, possibly opening up additional areas for equipment additions. Based on the indications of characteristics of the facilities in the typical site documentation provided, the sites visited, and the continuing trends toward smaller equipment, no DCS facilities constraints have been identified that would prevent the P/M concept from being feasible.

The variety of equipment (Army-Navy-Air Force) in current use across the DCS would pose considerable problems for any attempt to merge them into standard pallet modules. Since the study objective is to address the latest and subsequent generations of equipment, the variety should be less as the DCA and MILDEP standardization activities are implemented. The trend to digital solid state units eases the space/volume requirements on any given pallet, and their reduced power needs enable greater freedom in grouping or closer packaging. A related trend is the increasing degree of standardization in component circuit modules or subsystem building blocks for automated test equipment. An example of this trend was provided at the Industry Joint Services Automatic Test Equipment Conference in April 1978 at San Diego, where the results of the Navy's ongoing Standard Electronic Module (SEM) program were highlighted. Such modules enable combining many functions into one equipment unit that previously were in separate units or boxes. The P/M concept goes one step further by combining boxes into a module. Thus the next generations of equipment would have fewer separate units. However, each would be more complex because of its multiple functions, so that DCS-wide interface standardization at the unit/box level will be essential, e.g., as advocated in MIL-STD-187-310.

Changing constraints on the DCS equipment systems are evident in the operational concept for the Digital European Backbone Upgrade Program, i.e., to provide a new and improved terrestrial communications capability to enhance survivability and availability of the European DCS; to satisfy the requirement for new digital subscriber services; to reduce current logistics and O&M manning burdens by replacing obsolete equipment with modern, reliable, and easily maintained digital equipment; and to enhance the security of DCS transmissions by bulk encryption. The DEB system implementation will provide terrestrial wideband digital altroute connectivity between subscriber locations and Defense Satellite Communications System (DSCS) terminals to be deployed in Italy, the Federal Republic of Germany, and the United Kingdom. This connectivity reduces the required size and complexity of technical control facilities serving the DSCS, reduces manning, provides enhanced security, and improves end-to-end performance.

The DEB/MEP discusses the evolution of the DCS into a worldwide digital system. It will be engineered to be compatible and interoperable with other U.S. military and foreign systems where cost-effective. System design will permit interconnection of U.S. tactical force communications to support force deployments as outlined in JCS SM 486-75, 29 August 1975. Reconstitution packages will be deployed to promptly restore a backbone site in the event of catastrophic failure or destruction.

DEB system design and implementation must satisfy the paramount requirement to route critical subscriber traffic to its end destination even though major portions of the DCS have been destroyed, disabled, or otherwise denied. Equipment procured for rapid reconstitution may be used interchangeably for reconstitution, extension, or tactical interconnect purposes and will remain under the operational control of USCINCEUR. DCA will exercise operational direction over the equipment when installed to reconstitute or extend the DCS.

Reconstitution packages configured and procured under the DEB program must be capable of achieving an availability for the two adjoining links restored of no less than 0.99 when operating to reconstitute any DEB site or to extend DCS circuitry to new or tactical users. Necessary spares, prime power generators, etc., shall be incorporated into every reconstitution package to provide the requisite availability. The system gain of an operating reconstitution package will be sufficient to assure that the probability of equalling or exceeding a BER of 10^{-4} during any call minute shall not be greater than 5×10^{-5}.

Recognizing that the historical limitations of funding for reconfiguring and upgrading sites would tend to restrict the changes needed to accommodate P/M modules, the added implementation costs of the P/M concept must be offset by early payoffs. This will be possible if cost savings are realized in 1) module assembly and checkout by the supplier, and 2) reduced installation and checkout/cutover time.

The "DCS Plan FY 1980-1990", dated September 1978, projects a Total Obligational Authority (TOA) for the DCS of $950 million (constant 1976 dollars) each year for the 10 years. Of this amount, procurement is nominally $240 million and O&M (excluding military personnel) is $140 million. The P/M concept would involve new equipment procurement and site installations (an O&M cost), i.e., both the $240 and $140 million fundings each year.

The data below, extracted from Table 21-3 of DCA Circular 600-60-1, dated May 1976, indicates a substantial cost savings when the equipment is assembled, installed, and checked out as a transportable system at the vendor's plant, as opposed to on-site assembly, installation, and checkout.

Location	Pct. of Prime & Auxiliary Equip. Acquis. Cost
Vendor's plant	20
Normal, easily accessible site	40
Remote, hazardous site	60

Consequently, funding constraints as noted in the 10-year plan may be alleviated by the implementation of the P/M concept to realize possible dollar savings in procurement and O&M TOAs.

Additional potential constraints that should be monitored are foreign (host) nation approval requirements for real property acquisitions, site engineering changes, and new equipment installations. For example, the European Telephone System (ETS) is planned to be the DCS common user, general purpose, direct distance dial telephone communications network for the U.S. Forces in the European Theater. This system

will connect to the telephone systems of the local host country and to the European AUTOVON. The Federal Republic of Germany (FRG), as host for the larger part of the ETS, enforces its Telecommunications Ordinances through its Ministry of Posts and Telecommunications. Any new installations or new equipment that may impact the FRG telephone systems in any way must be submitted to the Ministry for evaluation and approval before it can be installed. It is not anticipated that such future, evolving constraints will impact the feasibility of the P/M concept.

2.3.5 Previous Studies

Efforts to identify prior studies conducted in recent years on the subjects of palletization or modularization of communications-electronics equipment included key word searches by the Defense Documentation Center, trade publication bibliography reviews, and contacts with MILDEP individuals. One consensus of such reports was that the stresses of transportation can be more hazardous to assemblies of C-E equipment than operational stresses. Experience has shown that equipment systems delivered intact to the users may be expected to perform as specified. The equipment designs typically are responsive to all anticipated operational requirements, and especially those that are well documented. It is generally true that user personnel can define and defend performance needs much more thoroughly than they can define and defend transportation and handling needs, especially for and under all possible combat conditions. Accordingly, many systems have failed to provide the same quality of performance in the field, as was observed at the factory/depot, simply because of degradation in transit, i.e., in transport and handling. This situation is being actively addressed by the DoD Engineering For Transportability Program.

DoD Directive 3224.1, "Engineering For Transportability", dated 29 November 1977, states as its purpose: ". . . to provide policy guidance and assign responsibilities for assuring that items of materiel, equipment and transportation systems are so designed, engineered, modified, and constructed that the required quantities can be efficiently moved by available means of transportation." Further, it defines Engineering for Transportability as ". . . the performance of those functions required in identifying and measuring the limiting criteria and characteristics of transportation systems; and the integration of these data into the design of materiel to utilize operational and planned transportation capability effectively. Limiting criteria and characteristics will include those created by standard unitizing methods (pallets, containers). Transportability engineering criteria will thus consider modularity to improve cube utilization and dimensional standardization for military cargo as well as maximum dimensions and total weight."

The action agency for administration of the Army (DA) portion of the DoD Engineering For Transportability Program is the Military Traffic Management Command Transportation Engineering Agency at Newport News, Virginia. MTMCTEA provides a central point for research, testing, and evaluation of transport criteria, and for their promulgation to new military systems designers. Added details of other MILDEP activities in support of DoD's program are provided in AR 70-44, Research and Development, DoD Engineering For Transportability. Supplementing this directive is MIL-STD-1366A, Packaging, Handling, Storage and Transportation System Dimensional and Weight Constraints, Definition of, dated 1 February 1977; this MIL standard will be discussed in detail in Section 2.3.7 of this report.

A report issued by DCA in December 1967, entitled Feasibility Study of Using Heavy Transportable Complexes to Satisfy Long-Haul Fixed Station Requirements, concluded that it was technically and operationally feasible to design, develop and utilize heavy transportable communications equipment for long-haul communications needs. The report cautioned that the economic aspects should be considered on a site-by-site basis because of the variability of installation costs for implementing fixed versus transportable communications facilities. A subsequent study by Collins Radio for the U.S. Navy (and DCA) was based on the use of off-the-shelf equipment, and led to the preparation in 1970 of the Technical Development Plan for Heavy Transportable Communications Equipment (HTCE). For various reasons, one being the large size of the then current off-the-shelf C-E equipments and the requisite large pallet modules, active development was not pursued. In the context of today's DEB I and new DRAMA equipments, the significant size (and weight) reductions in C-E equipment and smaller pallet modules, as noted earlier in Section 2.3.1, would additionally support the early (1967) conclusions on technical and operational feasibility.

2.3.6 Ongoing Programs

Identifiable programs in the MILDEPs with objectives similar to those of the P/M concept are conspicuous by their scarcity. The closest programs are TRI-TAC (AN/TRC-39) and the combat-oriented systems designed for rapid deployments, e.g., TIPI (Tactical Intelligence Processing and Interpretation); A-TACC (Automated Tactical Air Control Center); and various Marine Corps tactical command and control systems. All of these programs are by nature tactical and necessarily must meet tactical deployment objectives. The DCS as a strategic system has less dynamic requirements to meet, and generally functions in a more benign context, i.e., in fixed structures and with full supporting services. However, when the DCS requires new or added capability in emergency situations, temporary facilities (shelters or vans) will be used to house the C-E equipments until more permanent arrangements can be accomplished.

In many respects, tactical systems such as TRI-TAC may use similar equipment in similar racks or cabinets as the DCS currently employs. System arrangements, intercabling, access, and operator considerations are more severely space-limited in shelters and vans than at fixed sites. The palletizing and modularity developed for TRI-TAC is a solution developed for its particular context of requirements and constraints. The P/M concept for the DCS will have to meet similar van and shelter requirements as well as satisfying fixed site needs. The fixed site installation of the TRI-TAC equipment at Fort Gordon for training purposes may provide some useful guidelines for planning in the P/M concept design development, in terms of experienced differences in environmental requirements, observed equipment performance at a fixed site versus mobile units, etc.

Another program of interest is the Tactical Shelter Program under the guidance of the Joint Committee on Tactical Shelters (JOCOTAS). The committee includes representatives of the Army-Navy-Air Force organizations with interests in shelter, van, mobility and transport developments. The principal thrust of this program has been to promote standardization of transportable shelters and containers. For example, the latest recommendation by JOCOTAS is to reduce the numbers of standard rigid-wall ISO shelters from seven to four designs. Another recommendation developed jointly by the Navy and the Marine Corps for their Field Logistics System

(and also advocated by JOCOTAS) is the use of 8 x 8 x 20-foot containers as employed in international shipping on container ships. This is in accord with DoD Inst. 4500.37, which says:

> "DoD Components will insure that American National Standards Institute (ANSI)/International Organization for Standardization (ISO) container specifications are considered in programs involving purchases and/or long-term lease of shelters and/or special purpose vans."

Incidentally, it has been noted by Navy observers that the USSR military has frequently used these 8 x 8 x 20-foot containers for their shipments, suggesting a growing international acceptance and deployment of such standard containers and their associated handling equipment.

It is concluded that, although there are few fully relevant ongoing programs, features and considerations as noted above are pertinent to the DCS P/M concept and should be considered in the development of design criteria.

2.3.7 Transport

The determination of standard transport parameters and constraints for air, sea and land movements of DCS C-E equipment included commercial as well as military capabilities. Documentation and military regulation reviews were supplemented by visits to Sharpe Army Depot, a container consolidation point for transshipment of military equipment to the Pacific theater, and to Travis AFB to observe aerial port operations for air cargo to the Pacific theater. The majority of the specific data collected during this effort will be utilized in deriving pallet design criteria in subsequent study tasks. However, the primary aspects of the transport factors will be summarized here. In general, while factors have been identified that will bound the final design characteristics of a DCS pallet/module, no aspects of transport have been identified that will preclude the basic feasibility of the P/M concept.

Data summarizing size and weight constraints for air, land, and sea transport are contained in Tables 2-12 through 2-14, respectively. These data have been drawn from:

a. AFSC Design Handbook DH 1-11, Air Transportability, 23 October 1978.

b. USACC document CCP 105-6, Communications-Electronics Transportable Systems Staff Planning Guide, 1 November 1974.

c. Military Specification MIL-A-8421F, Air Transportability Requirements, General Specification for, 19 September 1973.

d. Military Standard MIL-STD-1366A, Packaging, Handling, Storage, and Transportation Constraints, Definition of, 27 April 1972.

In addition to the data given in Tables 2-12 through 2-14, MIL-STD-1366A provides overall guidance for cargo item size and weight constraints generally applicable for world-wide shipping. Items to be transported in van or stake-body trucks at some point in the shipment process should not exceed 78"H x 84"W x 222"L and 10,000 pounds. If the item is not to be transported by either of these means, the recommended criteria are 96"H x 96"W x 384"L and 11,200 pounds. MIL-STD-1366A also cites limits on items due to local handling by tactical forces and NATO forces. Although these dimensions are considerable smaller than the general all-mode criteria, it may not be reasonable to impose them upon the DCS P/M concept since the DCS installations will be performed by U.S. forces and are not intended for routine tactical applications. While no statistical data are on hand at this time, narrow winding roads in some host countries will necessarily limit transport vehicle sizes and inhibit their transit to sites, necessitating the use of nonstandard ground vehicles, local air lift, or fewer modules in smaller containers.

2.3.7.1 Air Transport

For the air transport data shown in Table 2-12, several other considerations are pertinent. Even though the larger aircraft can accommodate very large containers, the handling of DCS modules sized to maximum aircraft capacity could pose problems at CONUS and remote ground sites. In CONUS, for example, the aerial port at Travis AFB handles the palletizing of materiel for military airlift to the Pacific. Sharpe Army Depot, primarily a surface transhipment facility for Pacific cargos, also handles some airlift cargo; it routes its military airlift cargo to Travis and its commercial airlift cargo to nearby Stockton Airport. As a practical matter, Sharpe Army Depot in its activities over the years has evolved some working guidelines for its packing and loading of pallets and containers. These guidelines provide for individual pallet loads and containers not to exceed approximately 108"L X 88"W x 99"H for C-130/C-141, and 108"L x 88"W x 102"H for C-5A transport, with respective weights of 10,000 and 10,600 pounds. Sharpe Depot guidelines also indicate that any single van in the 20- to 40-foot length range should not exceed 42,000 pounds in gross weight. This guideline is somewhat less restrictive than MIL-STD-1366A, which recommends the following maximum gross van weights to avoid overstressing transport aircraft:

Van Length (ft)	Gross Weight (lb)
10	12,500
20	25,000
30	35,000
40	45,000

The MIL-STD-1366A values, it should be noted, provide compatibility with commercial aircraft as well as military. That standard also requires that any single item to be transported by C-130, C-141, or C-5 aircraft and exceeding either 96 x 96 x 240 inches in size or 20,000 pounds in weight shall be subject to air transportability analysis or test loading.

TABLE 2-12. AIR TRANSPORT CONSTRAINTS

Aircraft Type	Maximum Cargo Capacity			
	Width (inches)	Height (inches)	Length (inches)	Weight* (pounds)
C-5A	216	156	1,551	112,000-265,000
C-141	111	103	834	60,000-70,000
C-130	105	102	480	20,000-35,600
U-21	54	57	152	3,000
UH-1B/C/M	80	56	48	2,939-3,820
UH-1D/H	96	52	92.5	3,344
CH-47B/C	90	78	366	15,000-18,200
CH-54A/B Universal military pod	106	78	326.5	16,980
DC-8/707**	88	75	108	7,500

*Cargo weight capacity varies with aircraft model number and fuel loading.
**Commercial.

The data provided in Table 2-12 for rotary wing aircraft show only the overall dimensions of the cargo areas. It must be noted that several other physical factors limit the size of a module still further, if rotary wing transport is to be used. In most cases, the door openings to the cargo areas are significantly smaller than the cargo areas themselves. Further, in several of the aircraft, power plant or transmission elements protrude into the cargo areas, limiting the overall size and form of cargo items. Thus, rotary wing transport (other than external sling) would place much more severe constraints on module size than fixed wing transport.

From the data discussed above and in Table 2-12, it can be concluded that:

a. The P/M design guidelines should be constrained to an overall size envelope from 78"H x 84"W x 222"L to 96"H x 96"W x 384"L for general transport purposes, with shorter sizes to be considered in subsequent tasks of this study.

b. Rotary wing aircraft capacities would severely limit the size and weight of modules, if their use for transport were a DCS P/M requirement. Conversely, sizing of the modules to take advantage of general all-mode transport would restrict the use of rotary wing transport to only the larger such aircraft. The specific constraints must be considered during subsequent tasks.

c. There is no limit imposed by air transport capacities that appears to render the P/M concept basically infeasible.

2.3.7.2 Land Transport

Certain factors relevant to land transport do not appear in Table 2-13. Detailed data regarding worldwide rail transport constraints are not available. However, MIL-STD-1366A does offer guidance on overall cargo item dimensions. Figure 3 of that document indicates that an item measuring 96"H x 96"W should fit within the size envelope of most railroad lines of Western Europe and other standard- and wide-gage railroads. Figure 4 of the document suggests that an item 96"H x 96"W might barely be accommodated by narrow-gage systems, but the drawing detail and rail car structure are not defined well enough to rule out the possibility of problems.

With current equipment capabilities, the ground handling of large modules could present problems at remote sites. By the early 1980s, however, the Army plans to attain operational capability for a rough terrain forklift truck with a load capacity of 50,000 pounds. While the characteristics of the vehicle design are not well suited to its use in forward tactical areas, it should have a broad capability in sites where DCS facilities are installed. Its lift capacity also exceeds the MIL-STD-1366A recommended single item weights for air transport.

The overall conclusion drawn from the foregoing evaluation is that ground transport constraints do not appear to render the P/M concept infeasible. They will have to be considered quantitatively in establishing pallet design criteria.

2.3.7.3 Sea Transport

Sea transport constraints are generally the least restrictive of the three basic transport modes investigated. Table 2-14 shows that the hatch openings on all ship types examined are more than adequate to accommodate cargo items conforming to the MIL-STD-1366A all-mode guidelines. Gross weight of modules should not pose problems for most of the ships investigated, either, with only one of the 12 types having a self-contained boom lift capacity less than 15 long tons (33,600 pounds).

Two pertinent aspects of sea transport are not treated in Table 2-14: cargo lift capacities in ports and logistics-over-the-shore (LOTS) operational capabilities. According to MIL-STD-1366A, which cites the World Port Index (Ports of the World) as its data source, 85 percent of the world's maritime ports have lift capabilities of 112,000 pounds or greater, and 99 percent have lift capacities in the 13,440 to 109,760 pound range or greater. MIL-STD-1366A also summarizes U.S. Army LOTS lighterage fleet capabilities, showing cargo size and weight constraints for seven different vehicles. The narrowest deck level cargo width restriction shown is 104.25 inches, and the shortest vehicle length is 191.25 inches. The next shortest is 288 inches,

TABLE 2-13. LAND TRANSPORT CONSTRAINTS

Highway

	CONUS	Overseas
Max vehicle height (in)	162	150
Max vehicle width (in)	96	96
Max length, single vehicle (in)	420	394
Max length, tractor + semitrailer (in)	660	551
Max length, other combinations (in)	660	709
Max single-axle load (lb)	18,000	unk
Max tandem-axle load (lb)	32,000	unk

Rail (CONUS)

	Boxcar	Flatcar	Gondola	Drop Center*
Max length (in)	606	1,069	786	1,446
Min length (in)	486	488	630	626
Max width (in)	112	126	114	125
Min width (in)	101	102	91	100
Capacity (lb)	80-110K**	100-154K	100-154K	250-500K
Max door width (in)	192	---	---	---
Min door width (in)	66	---	---	---
Max door height (in)	118	---	---	---
Min door height (in)	95	---	---	---

*Limited availability - require advance planning.
**Up to 160K reasonably common; up to 200K available.

TABLE 2-14. SEA TRANSPORT CONSTRAINTS

Ship Design Number	Hatch Openings* (inches)	Max Deck Load (lb/ft^2)	Boom Capacity** (LTONs)
C3-S-33a	477 x 261	300	20/75
C3-S-37a	479 x 299	337-508	60
C3-S-38	480 x 360	336-495	50
C3-S-46	480 x 372	442-465	10/60
C4-S-1a	478 x 358	unknown	10/60
C4-S-1s	450 x 318	420-540	10/15
C4-S-1t	510 x 336	360-487	30
C4-S-1Qa	510 x 300 508 x 310	338-672	22/60
C4-S-57a	510 x 264	335-495	15
C4-S-60a	536 x 296	337	10
C4-S-64a	504 x 360 504 x 300	270-403	15
VC-S-AP2/3	268 x 432	335-540	30/50

Note: All designs offer vertical clearance of 168 inches or greater at some locations. Vertical clearance of 96 inches or greater is available in 82 percent of cargo holds in fleet composed of 1 ship of each design. Clearance of 84 inches or greater available in 98 percent of holds.

*Smallest and largest shown, if more than one hatch.
**Min and max boom lift capacities shown, if more than one.

and all others are 507 inches or longer. The smallest vehicle (LARC V) has a load limit of 10,000 pounds, the next smallest (LARC XV) handles 30,000 pounds, and all others can carry 120,000 pounds or more.

The general conclusion drawn from these data is that sea transport restrictions will not drive the P/M design guidelines unless the very smallest of ships, maritime ports, or lighters are deemed a DCS operational requirement. Even in such a circumstance, it is not evident that the restrictions imposed should impact to any extent the basic feasibility of the P/M concept.

2.3.7.4 Other Transport Considerations

In addition to the specific vehicle and handling parameters discussed above, the referenced documents were searched for other considerations that could impact P/M feasibility. No constraints or requirements were identified which can be said to limit the feasibility or applicability of the concept beyond those physical constraints. A variety of factors were noted and considered in selecting specific design criteria during subsequent study tasks.

2.3.8 Fixed, Mobile and Partial DCS C-E Applications

The characteristics of C-E applications for fixed, mobile, and partial applications of the P/M concept are addressed in the following sections.

2.3.8.1 Fixed Sites

Limited data were available on fixed-site facilities. It was evident, however, that the permanent and prefabricated building designs most representative of those currently utilized in DCS installations are typical of the World War II and 1950s period. Most installations were constructed with fixed instead of false floors. False floors came into widespread use with computer installations in the late 1950s and early 1960s to 1) accommodate the multiplicity of interconnections and cabling essential to computer input-output-processor unit associations, 2) facilitate use of plenum chambers and forced air ducts to service the separate units, and 3) avoid all dust sources and collectors, e.g., overhead cable trays and false ceilings in the computer equipment room. The DCS installations in the older buildings have generally improvised false floors by setting equipment racks on 4 x 4 wood beams to gain inter-cabinet cable ways to supplement the overhead cable trays. Air conditioning installations have been marginal in most sites because of the absence of provisions for such ducting and routing throughout the older buildings. In the absence of false ceilings, the personnel working areas in these buildings have been kept cooler. Adding site equipment (and higher power transmitters) to meet increased communications services requirements has compounded the problems of interwiring and cabling and environmental control. Fortunately, the new digital and solid state technology may help to alleviate this situation by reducing space and power (and cooling) requirements for equivalent site service capabilities, as compared to older analog equipments.

American Telephone and Telegraph, based on its extensive experience in facilities, installations, and equipment operation, has recently issued a Facilities Design Standard (New Equipment-Building System, NEBS) as a guide for construction of new or improved buildings for central office installations. A key recommendation

by AT&T is to use 20-foot centers for the ceiling-supporting columns. This spacing is generally compatible with P/M equipment modules that would fit readily in the standard 8 x 8 x 20-foot ISO/ANSI container for international shipping via sea, land, or air. Another recommendation is the provision of 10-foot clear heights for frames, cabletrays, and lights, i.e., the distance between the floor and the bottom of the lowest ceiling components such as air ducts or beams. The closest military counterpart of this height requirement is in the Technical Control Facilities document (CCTM 105-60-6), which calls for a 2-foot clearance above any cabletrays or racks and cabinets without citing any ceiling height value. Thus, P/M equipment modules would not pose any height problems. The floor loading capability cited by AT&T/NEBS is 150 pounds per square foot (live load) in the equipment spaces. DCS sites are essentially slab-on-grade installations and their floor load capabilities are at least 150 PSF, as noted in CCTM 105-50-6. This value limits the size of equipment pallets if lift trucks are to be used to move the pallets into position. The P/M modules on their pallets in the worst case are not expected to exceed 100 PSF effective loading, so that hand-operated "walkie" lift trucks can be used for their positioning without the necessity of using protective plates on the floor.

AT&T/NEBS directs that any equipment frame assembly when packaged for transport, should fit through the standard facility access entrance of 4 feet wide and 8 feet high. The candidate width of the P/M module pallet, as noted earlier in Section 2.3.1.3, is 44 inches, and would fit such standard facility equipment entrances. Further details of other AT&T-recommended facility guidelines are addressed in Task II, Design Development, for this study (see Annex A).

The DEB/MEP, in addressing general facilities criteria, directs that DoD Construction Criteria Manual 4270-1-M and applicable MILDEP manuals and regulations shall be used for all design and construction, and that at sites requiring new construction for buildings, maximum use shall be made of a standard design. Study efforts to date to investigate fixed-site facility developments by the MIL-DEPs have identified only one candidate for a standard design for DCS sites. This candidate is described in the DCA document, Combined Communications Building, Construction Design Criteria, Kanto Plain, Japan, dated 24 May 1978. This document describes a facility planned for construction at Yokota AB, Japan, to meet requirements of the future DCS in terms of survivability, sufficiency, energy saving, grounding improvements, radiation protection, TEMPEST, and growth potential. Further study efforts under Task IV, Future Applications of the P/M Concept, have considered this development.

2.3.8.2 Vans and Shelters

A major concern of this study is the applicability of the P/M concept across the worldwide DCS, primarily for the permanent sites and secondarily for the contingency reconstitution and tactical interconnect requirements such as cited in the Digital European Backbone System Management/Engineering Plan. This section addresses those secondary requirements and evaluates the characteristics of representative vans and shelters, and their potential utilization, e.g., for contingency reconstitution and/or tactical interconnect applications in the DCS. Because of the considerable concern by DoD in recent years for the standardization of shelters for military applications (DoDI 4500.37, DoDD 3224.1, and AR 70-59, Department of Defense Tactical Shelter Program), they will be considered first.

In its most simplistic definition, in terms of this study, a shelter is a container that must be capable of protecting equipment installed within it against the effects of worldwide climatic extremes. It must accomplish that mission after being subjected to the rigors of a multiplicity of transportation methods and handling, including tactical environments. These methods may include railroad, truck, fixed-and-rotary-wing aircraft, seagoing vessels, dolly or dedicated transporter systems, and primitive skidding. A shelter must insulate against temperature and electromagnetic environments and, as required, against ballistic and nuclear blast effects. Its function and sophistication fall between that required for truck body and aircraft designs.

The charter for the Joint Committee on Tactical Shelters (JOCOTAS), as cited in AR 70-59, defines a tactical shelter as: ". . . a presized rigid/expandable, transportable structure designed to meet functional requirements by providing a live-in/work-in capability. (Specifically exempted are fabric wall shelters, air-supported structures, refrigerated shelters, and modular or prefabricated structures designed to be shipped to the theater of operations and assembled with engineer unit support and containers.)".

Further, AR 70-59 states: 'This Charter applies to all DOD components engaged in supporting or requiring tactical shelter research, development and engineering. It encompasses all tactical shelter RD&E unless specifically exempted by the JOCOTAS and approved by OSD".

As the lead service for JOCOTAS, the Army through the senior shelter engineer at the Natick Development Center, who is acting as executive secretary of JOCOTAS, provided the data on the latest recommendations of shelter standardization by the JOCOTAS committee as shown in Figures 2-15 and 2-16, and Table 2-15.

These four JOCOTAS-proposed models would standardize Army shelters, thus eliminating the proliferation of specialized shelters previously designed by separate Army agencies. The standardized shelters would be outfitted with various specialized kits so that they can be used for many different purposes: administrative, communication, fire control, maintenance, medical, storage, supply, or housing.

All of the proposed shelters have a box-like shipping exterior that conforms to the structural and dimensional requirements of cargo containers for all modes of transportation. However, most of them are not limited to their shipping size, but can be expanded by simply folding out the walls. For example, all of the shelters have the same basic 8 x 8 x 20-foot shipping exterior. For one model, this is the total shelter size. In the succeeding two models, however, the walls are modified so that they fold out into extensions that double or triple the interior space of the shelter. In the fourth model, the walls are extended by "accordion shells" that increase the interior space by almost seven times, providing 1,000 square feet of working area.

The floors, walls, and roofs of these shelters are made of paper honeycomb bonded between sheets of aluminum. The jointed accordion shells consist of urethane foam cast between sheets of embossed stainless steel. This construction has proven effective for its insulating properties as well as its strength. Each shelter has an internal electrical system and leveling jacks, and can be equipped with a heating/air conditioning system.

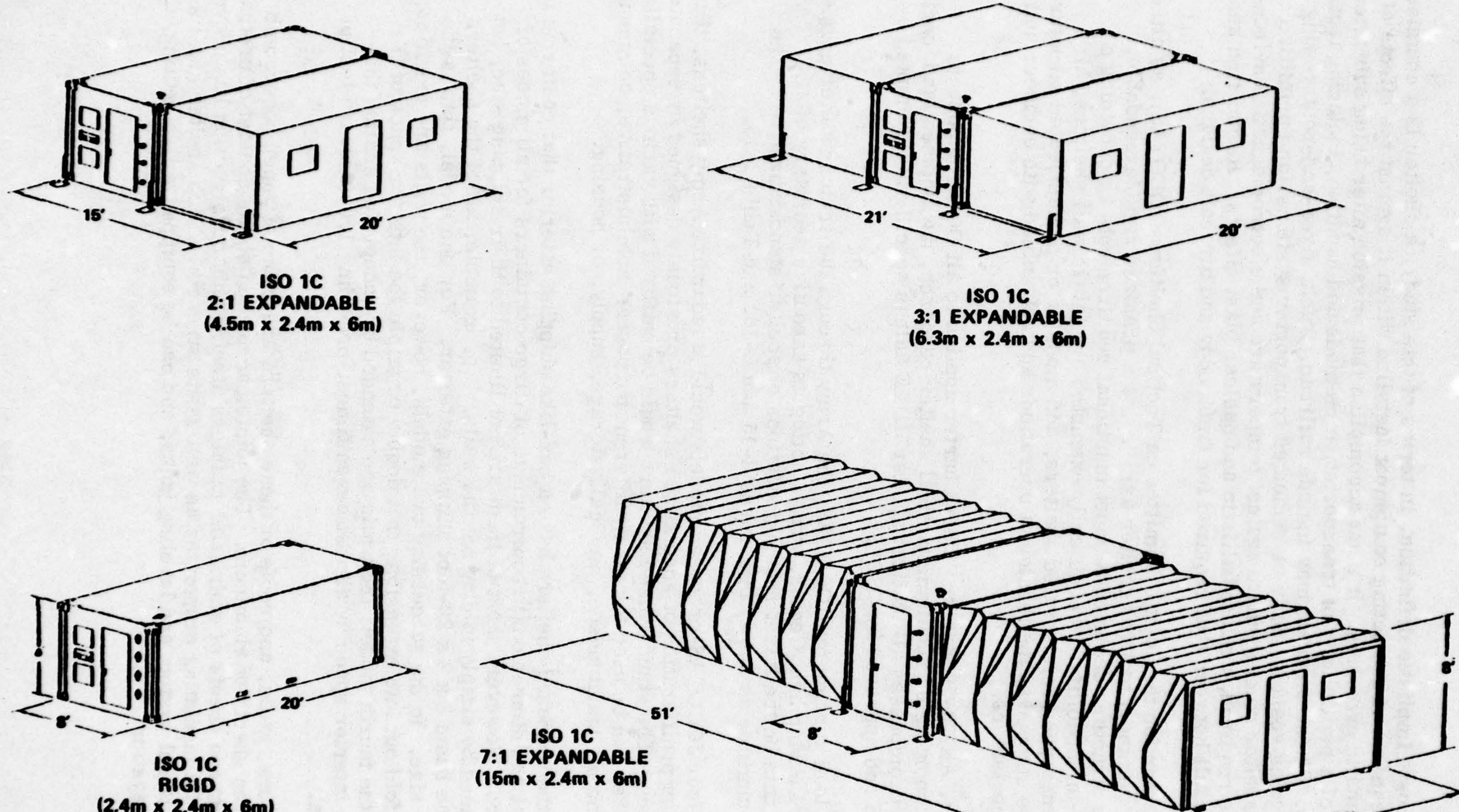


Figure 2-15. Family of Standard Rigid Wall ISO Shelters (Joint Committee on Tactical Shelters — JOCOTAS)

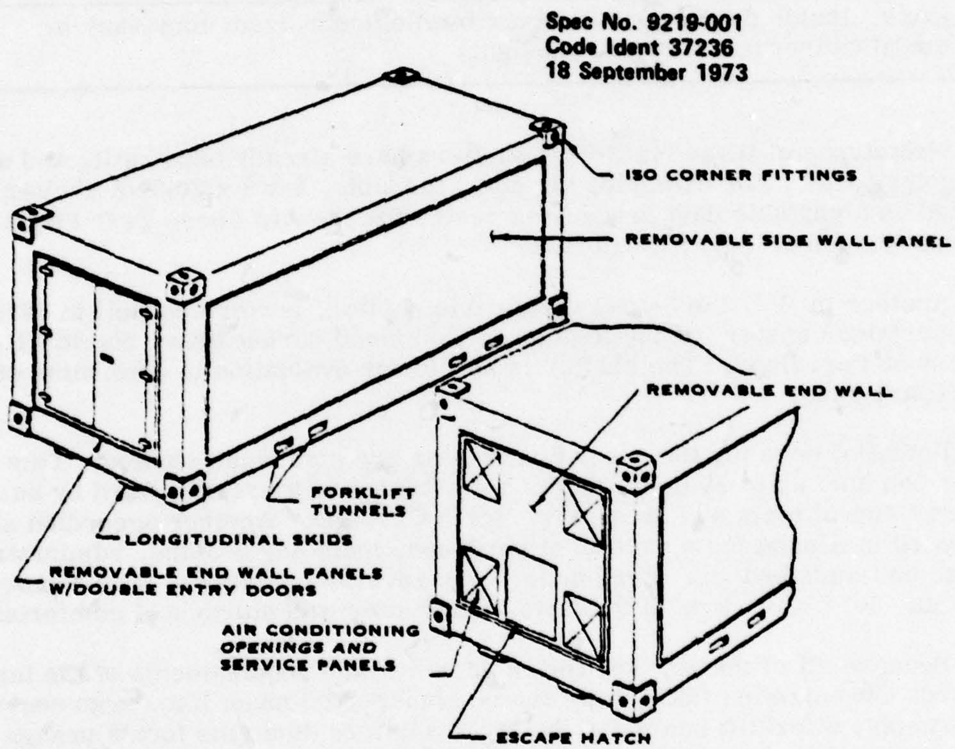


Figure 2-16. Example Sketch of ISO Shelter (U.S. Marine Corps)

TABLE 2-15. STANDARD RIGID WALL SHELTERS (JOCOTAS/NATICK)

Model	Type	H (ft)	W (ft)	L (ft)	Notes
ISO-IC	Rigid	8	8	20	Not expandable
ISO-IC	2:1 Expandable	8	8	20	One side removable
ISO-IC	3:1 Expandable	8	8	20	Two sides removable
ISO-IC	7:1 Expandable	8	8	20	Two sides removable
(Note: Inside dimensions have not been standardized; may vary by manufacturer and structure design.)					

Prototypes of these rigid-wall shelters have already been built, and are now undergoing tests. For example, the nonexpandable, 8 x 8 x 20-foot shelter has been outfitted as a portable data processing center for the Air Force Test Flight Center at Edwards Air Force Base, California.

Another model, the 3-to-1 expandable shelter, performed well in 1975 as a joint operations center for the Readiness Command during Brave Shield XII, a field exercise at Fort Hood. The shelter is now under evaluation to determine other possible military uses.

Potential uses for the accordion shelter are also being studied. This large shelter can hold up to 20 beds, and is being tested as a hospital ward by an Army Surgeon General team at Fort Bragg, North Carolina. Another accordion shelter was tested in Alaska for a variety of purposes, including housing, administrative offices, and maintenance. Even under very adverse conditions, with temperatures as low as -50°F and winds of 50 knots, the shelter was sturdy and comfortable.

Because all of the new shelters conform to the requirements of the International Standards Organization (ISO), they can be transported much like cargo containers. For example, a forklift can move the large shelters since the fork's prongs fit easily into custom-made slots built into the base of the shelter. For storing and shipping, up to six shelters can be stacked. When a crane or helicopter is used for hoisting a shelter, lines are attached to special corner fittings. With the addition of a transport dolly, such as the Type III rough terrain GOAT transporter and full undercarriages with lights, brakes, and suspension per MIL-M-8090, a shelter can be towed as a trailer. The new ISO shelters will therefore be much easier to transport by rail, water, highway, or air.

Because of new design concepts, units of the proposed Family of Standard Rigid Wall ISO Shelters are not only multipurpose but also easy to transport and convenient to use. Two of these four shelters (the 2:1 and 3:1 expandable types) are included in this study's SOW, which cited seven representative military shelters for consideration. These specific shelters are described in Table 2-16, using data provided by Craig Systems Corporation and Gichner Mobile Systems, a Division of the Union Corporation. Recent shelter models are fitted with ISO corner fittings to enable sling and helicopter hoisting. The H-762 model is an old design with round corners and not suitable for mounting ISO corner fittings. In all other respects, the listed shelters are MIL-qualified and suitable for DCS P/M equipment applications, subject to such equipment installation and operational factors as payload limitations, height and door clearances, and EMI and TEMPEST tests.

TABLE 2-16. REPRESENTATIVE RIGID WALL SHELTERS
(Cited by SOW)

Manufacturer and Model†	Outside Dimensions* (Inside Dimensions)**			Notes	Shipping Payload (lbs)
	H	W	L		
Craig H-752	8 ft (86 in.)	8 ft (88 in.)	10 ft (110 in.)	Removable end and double door 69 in. x 60 in.	5,000
Craig H-753 (ISO 3:1 Expandable)	8 ft (86 in.)	8 ft (88 in.)	20 ft (230 in.)	Removable sides and double door 69 in. x 60 in.	10,000
Craig H-754	84 in. (80 in.)	86 in. (82 in.)	132 in. (128 in.)	Joining corridor for 752/753	-
Craig H-686	7 ft (75 in.)	87 in. (81 in.)	10 ft (111 in.)	S-280 design; door 65 in. x 35 in.	4,000
Craig H-687	7 ft (75 in.)	87 in. (81 in.)	20 ft (111 in.)	S-280 design; door 65 in. x 35 in.	8,000
Craig H-760 (ISO 2:1 Expandable)	8 ft (86 in.)	8 ft (88 in.)	20 ft (110 in.)	One side removable and double door 69 in. x 60 in.	10,000
Craig H-762	8 ft (86 in.)	8 ft (88 in.)	12 ft (110 in.)	1950's Pershing shelter design	5,000

†First six models have ISO corner fittings
*Data provided by Craig Systems Corporation
**Representative dimensions

The shelters that have removable sides or ends, such as H-752, -753, and -760, have no constraints on clearances for installation of equipment modules. Other shelter types, such as H-686, -687, and -762, would place limitations on equipment module designs because of their door sizes (65"H x 35"W), if their use were allowed to drive the module design. Shelter H-754 is a joining corridor that is stored in the fully-folded form (walls and roof fold in and onto its floor); in use it becomes a passageway for connecting shelters. Any equipment to be installed in a joining corridor would have to be placed in position after deployment and erection of the unit. Shelters H-753 and H-760 are representative of two of the four JOCOTAS-recommended standard shelter designs for tactical military applications, such as for the DEB contingency reconstitution and tactical interconnect requirements.

The special purpose vans noted in the SOW for consideration are listed in Table 2-17, with data provided by technical manuals and the U.S. Army Natick Reference Manual on Shelters, 1972 (final) edition. The semi-trailer vans such as M-348, M129A2, and XM-433 are basic mobile shelters in wide use by many Army agencies for electronic equipment applications (see Figure 2-17). Data on the XM-557 and -558 vans show them to be the later designs with larger payload (weight) capability.

TABLE 2-17. REPRESENTATIVE SPECIAL PURPOSE VANS
(Cited by SOW)

Model	Type	Overall Dimensions*			Notes	Cross-Country Payload (lb)
		H	W	L		
M348A1	Semi-Trailer	92 in.	8 ft	27 ft	Rigid wall; dble door 6 ft x 4 ft	6,000
M348A2	Semi-Trailer	92 in.	8 ft	27 ft	Rigid wall; dble door 6 ft x 4 ft	6,000
XM433	Semi-Trailer	92 in.	8 ft	27 ft	Rigid wall; dble door 6 ft x 4 ft	7,000
XM557	Semi-Trailer	93 in.	8 ft	28 ft	Rigid wall; dble door 6 ft x 4 ft	14,700
XM558	Semi-Trailer	93 in.	8 ft	28 ft	Rigid wall; dble door 6 ft x 4 ft	16,700
M313	Semi-Trailer (Expands)	87 in.	7 ft	17 ft	Expands to 168 in. W; dble door 6 ft x 4 ft	12,000
M291A2	Truck, Van (Expands)	87 in.	7 ft	17 ft	Expands to 168 in. W; dble door 6 ft x 4 ft	10,000
M292	Truck, Van (Expands)	7 ft	8 ft	17 ft	Expands to 168 in. W; dble door 6 ft x 4 ft	5,000
M820	Truck, Van (Expands)	8 ft	8 ft	16 ft	Expands to 167 in. W; dble door 6 ft x 4 ft	5,000

*Data provided by TMs and Natick (USA) Reference Manual on Shelters, 1972.
Inside height is typically 12 inches less than overall height as shown, and inside width is 8 inches less than overall width as shown.

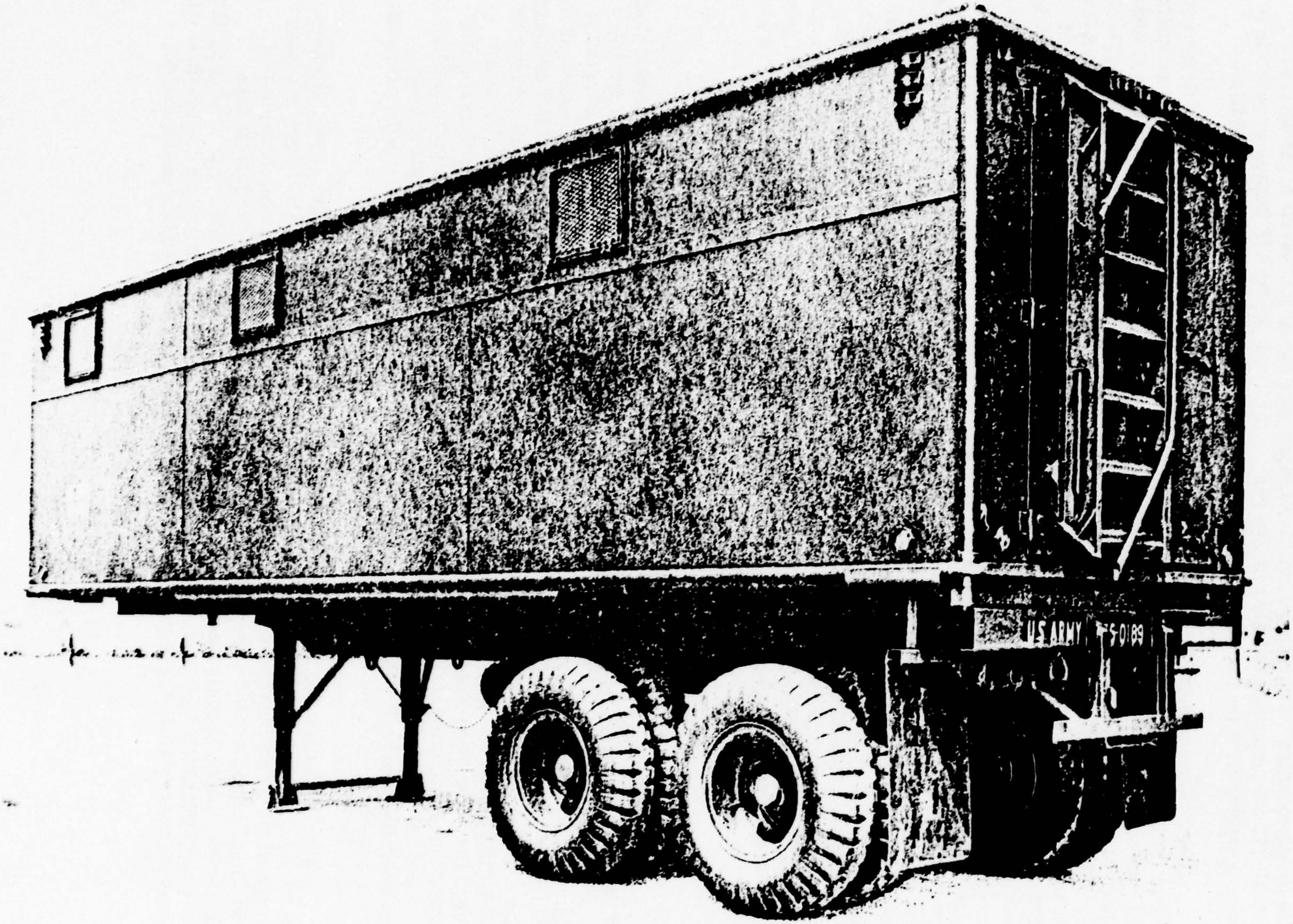


Figure 2-17. Example of Van, Semi-Trailer – M129A2 U.S. Army Natick Labs Reference Manual on Shelters, 1972

The cross-country payloads as noted could be increased for paved highway travel. The M-313 van can be expanded in internal width from 82 to 162 inches to provide a large working area as for command post and equipment maintenance activities.

These vans are transported by driveaway, rail or air. They are not fitted with ISO corner fittings for helicopter lifting. The vans can be equipped with air conditioners and multi-fuel heaters, externally mounted as required. Access for equipment installation is nominally standardized in the form of double doors in the back end of the vans, which limit rhe size of equipment modules or units. An additional door or doors for personnel use is/are located in the side(s) of the vans. Typical construction is of aluminum and plywood on a steel undercarriage to enable cross-country (off-highway) carriage of payload weights exceeding those of most radio and electronic equipment.

The truck vans, M-291, -292 and -820, are of the expandable type (see Figure 2-18). Principal uses have been as instrument calibration shelters, meteorology instrument shelters, and photo reproduction shelters. A maintenance problem has been encountered in the expansion joint seals leaking under wind-driven rains. Air conditioning and heater units are mounted above the truck cab on the front end of the van. The construction characteristics of the truck vans are similar to those of the semi-trailer vans in that they are designed to transport payloads that typically are heavier than those of radio and electronic equipment. Access for installation of payload equipment is through double doors at the rear of the vans, which also serve for personnel entry/egress.

2.3.8.3 Partial Applications of the P/M Concept

Partial applications of the P/M concept, e.g., the development of module configurations for certain types of equipments or terminals, but not for large unwieldy systems such as the current AUTODIN switching centers, represents an attractive approach to the implementation of the P/M concept. This approach is illustrated in this study (Section 2.3.1, DCS Equipment Survey) by the use of the Digital European Backbone (DEB) Stages I-IV upgrade equipments as candidates for palletization and modularization. A minimum of 85% of the C-E equipments involved in the site upgrades were seen to be compatible with palletization and modularization requirements for implementation of the P/M concept. Thus, the programmed transition of the DEB network from analog to digital operations could appropriately have initiated the use of P/M modules of the C-E equipments, assuming proper preparations and coordinations had been accomplished.

The use of the partial application approach to implementation of evolutionary upgrades minimizes risks of service breaks and of unknowns in DCS network interoperability. The magnitude of the DCS, with its hundreds of variously equipped and interlinking sites and multitudes of users and their service requirements, precludes major transformations except on an evolutionary basis. Accordingly, the partial application approach to implementation of the P/M concept in association with an evolutionary DCS upgrade program warrants earliest possible consideration.

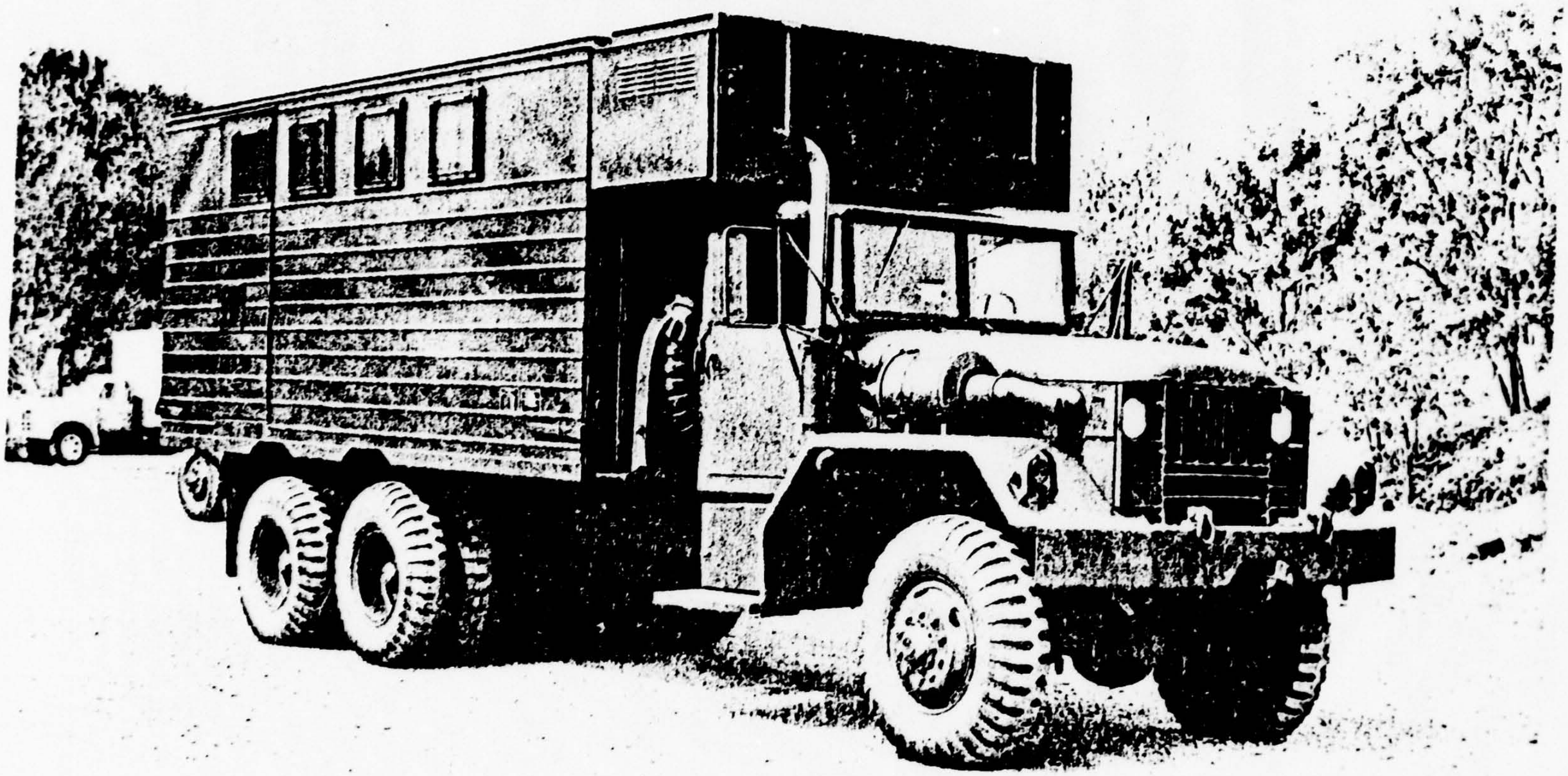


Figure 2-18. Example of Truck, Van, Expandable – M291A2 U.S. Army Natick Labs Reference Manual on Shelters, 1972

2.4 RISK ASSESSMENT OF P/M CONCEPT IMPLEMENTATION

This phase of the Task I feasibility analysis addresses the nature and levels of any uncertainties or risks involved in implementing the P/M concept. This determination will proceed on the basis of six characteristics deemed essential for a successful implementation, which are:

Characteristic	Definition
1. Module design	The basic structure and installation techniques
2. Producibility	Capability to manufacture, assemble, and test modules
3. Transportability	Handling, transhipment, and installation
4. Interoperability	Operation of modules in DCS sites worldwide
5. Operational Support	Supply, maintenance access, and repair
6. Cost Effectiveness	Acquisition, test, deployment, and operation costs.

In this evaluation, maximum use of references to existing Army-Navy-Air Force system and module developments will be made to provide comparable examples.

Measures of the levels of risk or uncertainty involved in the particular assessments will be indicated on the basis of engineering judgment as:

a. Negligible – No recognizable questions or indications of risk

b. Small – Indications of possible difficulties of a minor nature

c. Medium – Indications of difficulties surmountable with added time and cost

d. High – Indications of possible problems requiring new approach or major development time or cost to resolve.

2.4.1 Module Design

The development of C-E equipment modules has been evidenced in recent years in tactical military command, control, and communications systems. The emphasis on increasing the military capability to respond to crisis or emergency situations in shorter times with specific and measured force has fostered mobile and transportable systems. Examples of such systems are the A-TACC (Automated Tactical Air Control Center, of the Tactical Air Control System); TIPI (Tactical Intelligence Processing and Interpretation); and DASC (Direct Air Support Center of the Marine Tactical Data Systems). These systems have taken major equipment modules such as computers, display consoles, communications centrals, and switchboards, and packaged them for installation in field shelters at austere or "bare base" locations. Such modules provide communication services, data handling and control functions, and man-machine interfaces, which are generically similar to those of DCS equipment.

Each such module contains great numbers of electrical interconnections. It is general practice to assemble, integrate, and check out each module at the factory instead of in the field. Each module is fitted with keyed connectors that enable quick and proper hookups under field conditions.

Field exercises have demonstrated in deployments of A-TACC, TIPI, and DASC units that the severe design requirements can be met. Such design requirements are more stringent than would be needed for P/M module installations in DCS fixed-sites, but for emergency or contingency activations of tactical interfaces or of DCS site restorals, the requirements could be comparable. Thus, implementation of the DCS P/M concept would not pose new, unusual, or greater design requirements than have been met in numbers of other military C-E systems, so that the design risks would be small to negligible.

2.4.2 Producibility

The uncertainties involved in the potential producibility of the P/M concept modules are determined by the existence or possible discovery of any new or special requirements for tooling, manufacture, assembly and test. Pallets have been devised and employed to support, secure, position, and protect electronic assemblies ranging in size up to AT&T's van-sized ESS No. 3 switching central. Electronic warfare pods have enclosures around electronic equipment pallets for aircraft use. The I-beam framework supporting the three equipment bays of cabinets of the ESS No. 3 is a very large pallet. The individual rooms of equipment that are preassembled, tested, and warehoused at Litton's Pascagoula DD-963 (Spruance class destroyer) facility are actually enclosed palletized modules that are lowered into the hull and interconnected to make up the decks of the destroyers.

The development of pallets for modules of equipment is a mature technology; the application of pallets to support similar new C-E modules has been demonstrated in A-TACC, DASC, etc. Consequently, the uncertainty in potential producibility of DCS P/M modules should be small to negligible.

2.4.3 Transportability

Advances in cargo preparations for shipment by surface or air have appreciably reduced the built-in protection previously needed in C-E equipment. Commercial and military transportation services, based on extensive experience in assessing the vulnerability of cargoes to the shocks and vibrations of transport, have evolved appropriate protective means to be used in shipping. AR 70-44 directs early transportability assessments by the Military Traffic Management Command to identify potential problems. The principal problems of uncertainties have been noted and resolved in tactical equipment system transports that must go off-road to their destinations. The DCS modules are not expected to be transported in Army trucks or vans in off-road routings unless they are properly prepared in shipping configurations. While vibration and shock loadings can be high during such transport, the risk to the DCS modules is not anticipated to be greater than to any other military electronic equipment transported to remote sites. Helicopter lifting is an attractive alternative to off-road transport. Candidate module sizes and weights derived in Section 2.3 have been shown to fall within the bounds of worldwide transportation requirements.

At the destination of the P/M modules, installation will involve removing their shipping containers to facilitate site equipment-handling procedures involving, for example, forklift trucks, dollys, air-cushion pallets, etc. Movement into the facility will not pose any new constraints or requirements that have not already been solved for large air conditioning units, uninterruptible power supplies and generators, and central battery power supplies. Thus, in normal or peacetime situations, transportability of P/M modules should evidence small risk in light of established capabilities and experience. The module sizes discussed in Section 2.3 have been selected with on-site handling constraints in mind. Against the uncertainties in combat or contingency situations, transport capabilities as noted in Section 2.3.7, plus the exercise of "commendable initiative" by commanders, should be adequate to handle P/M modules on a worldwide basis.

2.4.4 Interoperability

The development of P/M modules for the DCS requires the concurrent development of provisions for accommodating them at the scheduled using sites and in reconstitution packages, e.g., vans and/or shelters. The fixed sites will require engineering activities directed toward establishing suitable equipment and power interfaces and cabling interconnects to enable and exploit quick setup, checkout, and activation of the P/M modules. The vans and shelters will require installation design and engineering. Because the DCS has nearly 600 sites, careful programming and scheduling of such site modifications will be necessary. The actual changes required at Army sites may well be different from those at Navy or Air Force sites because of the nature of local site facilities, equipment layouts, associated tactical equipment, and support interfaces. Consequently it will be essential that the approval of any P/M module specification reflects adequate consideration of possible standardization versus the cost and impact on all MILDEP DCS sites. For example, it might not be cost-effective to standardize an equipment of limited use.

The van and shelter applications of P/M modules must permit interconnection of U.S. tactical force communications to support force deployments as outlined in JCS SM 486-75, 29 August 1975, subject: "Joint Multichannel Trunking and Switching System (JMTSS)". Reconstitution packages will be deployed to promptly restore a backbone site in the event of catastrophic failure or destruction. Two basic requirements exist for tactical interconnect and contingency reconstitution. The first requirement is to reconstitute a DCS node where VF channel drops exist. The second requirement is to provide a tactical interconnect at or reconstitute a remote repeater site. Each reconstitution package will provide for VF interconnection to external tactical or commercial subsystems. The reconstitution package should require only on-site mechanical assembly and disassembly.

The special requirements as noted above (*cited in the DEB MEP*) pose conventional engineering and design problems for van and shelter applications where space is limited. The fixed sites with their growth provisions are not known to have any unsolvable space constraints, so that their engineering and design problems are less. Since interoperability is essential to a viable DCS when reconstitution is necessary, the pacing factor is the van and shelter accommodation of P/M modules. The efforts to resolve this requirement can benefit from the experience gained in the TRI-TAC AN/TCC-39 program. The risks are seen to be nominally small.

Specifications for the AN/FRC-170, TD-1192, and TD-1193 cite interconnect connector locations and types, cable types, and bit rates compatible with current FKV/DEB digital installations. No fiber optic or other exotic interfaces are specified for those units. It is concluded that the interfaces to and interoperability with other DCS equipments represent no unusual risks.

2.4.5 Operational Support

The provision of adequate operational support must be detailed in the P/M module maintenance plan, which is a product of the system engineering of the P/M concept design. Recent trends (as exemplified in the DEB MEP) have been toward a site repair philosophy that emphasizes field removal and replacement for failed assemblies, with piece-part repair at depot or factory facilities. Built-in test (BIT) capabilities for P/M modules could identify the defective replaceable unit without requiring expensive support equipment or highly skilled technicians at each site. For example, a recent report by Gaertner Research, Inc. (AD-A005 277) supports the conceptual feasibility of modular maintenance for field repair by minimum skill level personnel without sophisticated test equipment for the AN/PRC-77 radio set.

With regard to equipment planned for the DCS, the specifications for the AN/FRC-170, TD-1192, and TD-1193 all call for built-in test capability to fault-isolate to the replaceable module or card level. The maintenance concept of those equipments specifies that fault repair will be by replacement of unserviceable modules, printed circuit boards (PCBs), and parts that are not affixed to modules or PCBs. No repair of modules or PCBs will be done on site.

Recent microprocessor and preprogramming developments have reduced the complexity and cost of BIT capability for many applications. Research is being conducted at a number of companies now to perfect on-wafer interconnection of LSI chips to provide highly complex functional units without separating the chips, packaging them individually, and reassembling them on circuit boards. Such units will include some level of chip redundancy, with BIT circuitry isolating failures and switching in replacement (standby) ships automatically. Widespread use of such techniques, economically practical as LSI costs decrease, could further reduce on-site maintenance activities and costs for replacement spares. The risks in realizing the operational support to meet MTTR and MTBF objectives are greatly reduced by the increasing use of solid state components, so that the levels of such risk in this P/M concept employment should be small to negligible.

2.4.6 Cost Effectiveness

Considerations of the comparative costs of implementing and employing the P/M concept can be identified on a preliminary basis in the following areas:

a. P/M module RDT&E costs

b. Acquisition and deployment costs

c. Current and projected costs of present practices.

The RDT&E costs can be minimized through "open-forum" specification development such as used by the commercial airlines through the Airline Electrical Engineering Committee sessions. Technical representatives of the major airlines and the MILDEPs openly discuss new equipment developments applicable to commercial aircraft use with candidate equipment suppliers, and jointly develop refinements for minimum equipment performance and interface specifications. The USAF has recently used this same technique in its Inertial Navigation System acquisition program for the F-16, with potential application for F-15 and F-18 units. Following this open forum specification development, three vendors have been funded to provide prototype units for evaluation. In this approach, assuming that all units are qualified, the Air Force will have three candidate sources for the interchangeable INS equipments and can benefit from open competition. In a similar approach, for the P/M concept implementation, a select committee of DCA, Army-Navy-Air Force, and equipment supplier representatives can be assembled to discuss and define candidate equipment modules in terms of minimum performance and interface specifications. Subsequently, after suitable system engineering and design development, the lead service would solicit prototypes from interested suppliers for qualification and field tests. Thus, RDT&E costs would be limited to specific objectives with a minimum of associated development requirements.

The acquisition costs for the modules would gain the benefit of quantity setup, assembly, and checkout at the supplier's plant. Factory assembly and checkout of modules, followed by assembled shipment to the DCS site, can provide savings in addition to quantity production. For example, Table 1-2 of DCA Circular 600-60-1, "DCA Cost and Planning Factors Manual", May 1976, shows an estimated cost of $66,600 for in-factory system integration and assembly of a "Proposed Subsystem/Project Plan X-7X LOS Microwave System". This compares with an estimated cost of $532,600 for system assembly, installation, and checkout at the deployment site. (The equipment is disassembled for shipping after factory checkout.) The same cost elements for a "Proposed Subsystem/Project Plan X-8X Tropospheric System" (Table 2-3 of DCA CIR 600-60-1) are $99,400 and $794,900, respectively. The advantages of applying labor to system assembly and testing in CONUS factories versus overseas sites are shown in the data in Table 24-15 of the DCA circular. Annual rates for a C-E lead engineer are $42,000 in factory versus $64,000 overseas. The same two annual rates for technicians, loaded with per diem, overhead, and profit, are $21,000 and $37,000. Thus, the basic labor rates overseas are 1.5 to 1.75 times as high as in CONUS factories, with further in-plant savings anticipated due to higher efficiency and better support resources than at field sites.

The transition to digital transmission techniques and solid state equipment may provide additional cost savings beyond those noted in palletizing and modularizing. A typical site upgrade involves the following cost items, in addition to prime equipment:

Cost Item	Purpose
Engineering/installation	Site engineering and manpower for accomplishing the installation of new equipment
System cutover	Transition from old system to newly installed system
Initial repair parts	Provision of initial supplies of repair parts at the support centers (maintenance echelons)

Test, measurement and diagnostic equipment	Provision of test equipment at sites and support centers
Transportation	Packaging and transhipment of equipment to site from manufacturer
Documentation	All site engineering plans and drawings, and maintenance and operators manuals

Cost data developed over the years for these factors have typically been cited as percentages of equipment acquisition costs. Updated (1978) estimates for these factors, based on a proposed upgrade of ETS telephone switch gear using new electronic digital switches, show lower costs for all factors except documentation. The factors were lower by ratios as high as 4:1, with the sum of all cost items listed above down to 63 percent of prime equipment costs, versus 109 percent using previous factors.

The overall conclusion drawn from the preliminary cost factors discussed above is that the P/M concept is highly likely to result in cost savings in several major areas. More detailed cost assessments are made during Task III, treating pallet procurement costs and site transition costs as called for in the statement of work for the study.

2.5 CONCLUSIONS AND RECOMMENDATIONS

This first task of this study examined the basic feasibility and probable scope of applicability of a Defense Communications System communications-electronics palletization/modularization concept enabling rapid installation, recovery, and relocation of DCS C-E equipment and related support equipment.

The study approach included equipment and technology surveys as well as contacts with organizations and agencies having relevant expertise. Extensive reviews of DCS requirements and planning documents, standards, and military regulations, specifications, and manuals were accomplished. Particular attention was devoted to 1) transportability considerations and developments, and their implications for the P/M concept and its implementation, 2) identification of current applications of similar modularization concepts, and 3) indications, through specific examples of actual DCS sites and plans, of the feasibility and applicability of the concept.

Conclusions developed are presented in Section 2.5.1, and recommendations for applicability of the P/M concept are given in Section 2.5.2.

2.5.1 Feasibility of P/M Concept for DCS

The P/M concept is seen to be an application of established technology and techniques that have been demonstrated in comparable operational military systems. Further, candidate module configurations have been formulated and successfully applied to a variety of actual current and planned DCS sites. The digital C-E equipment at those sites were found to be compatible with the candidate configurations.

It was also found that implementation of the P/M concept would exploit the more advantageous factory assembly and test resources of CONUS facilities, as opposed to

DCS site assembly resources, for the upgrades of site capabilities. Modification of existing DCS sites to accommodate P/M concept modules can be accomplished by preplanning for inside plant structures, cables, and interfacing connectors; and providing installation space to be used when modules are delivered to the sites.

Design and system engineering for van and shelter installations of reconstitution packages of DCS C-E equipment will pose no great difficulty. Preliminary assessments of candidate P/M modules show compatibility with ANSI/ISO shelters and containers, so that the transportability problems would be minimized.

While the costs of implementing the P/M concept have not been investigated in any detail at this point in the study, the application of similar concepts to operational fixed-site systems has not indicated any cost parameters that would preclude application of the P/M concept to the DCS. Further, similar concepts for both tactical and fixed-site communication facilities have been implemented and have demonstrated feasibility in operational deployment.

Consequently, the conclusion of this investigation is that the P/M concept is technically feasible for implementation within the DCS. Table 2-18 summarizes the results of risk assessments of the principal determinants of the concept feasibility.

TABLE 2-18. TECHNICAL FEASIBILITY OF P/M CONCEPT

Consideration	Potential Problems and Risk	Impact of Risk
Module Design	None – technology in wide use	Negligible
Producibility	None – technology in wide use	Negligible
Transportability	Military contingency requirements	Small
Interoperability	Military contingency requirements	Small
Operational Support	None – BIT/solid state technology	Negligible
Cost-Effectiveness	MILDEP/DCA configuration control	Small

2.5.2 Probable Scope of Application of DCS P/M Concept

The applicability of the P/M concept to the worldwide DCS was projected from its hypothetical use in 1) the current FKV and DEB I subsystem of the DCS, and 2) the planned DEB II, III, and IV upgrades as detailed in the latest DEB Management/Engineering Plan. The types of functions that were upgraded or converted (analog to digital) in the FKV and DEB I were found to be compatible with the P/M concept, i.e., the equipments involved would fit the basic P/M envelopes.

Comparing these FKV and DEB I functions with similar functions presently employed across all DCS sites showed widespread application, as summarized in Table 2-19. This projection is consistent with DCA planning for the conversion of the DCS terrestrial transmission subsystem from analog to digital, wherein the FKV and DEB I represent the initial steps. Thus, this projection indicates the proportion of the DCS sites that could use the P/M implementations of FKV and DEB I functions, assuming that the P/M modules were available.

TABLE 2-19. POTENTIAL CURRENT APPLICATION OF P/M CONCEPT

Examples for Functional Modularization	Pct. Application	
	FKV and DEB I	All DCS
Transmission medium (line-of-sight radio)	100	63
Multiplex	100	69
Patch and test	100	67

For the future upgrade equipment scheduled for the DEB II, III, and IV, an assessment of suitability for mounting in P/M module envelopes was made. The numbers of P/M compatible equipment were determined from the MEP, as shown in Table 2-20. Thus, the proportion of DEB II, III, and IV equipment suitable for P/M implementations provides a strong indication of the eventual proportion of similar equipment that would be used in the DCS conversion from analog to digital transmissions. Extrapolations from available data indicate at least 39 percent applicability across the future DCS, with a higher proportion considered highly likely.

TABLE 2-20. POTENTIAL FUTURE APPLICATION OF P/M CONCEPT

Upgrade Equipment Suitable for Modularization	DEB II, III, IV	All DCS
Total equipments scheduled	2,134	(TBD)
Equipment in P/M modules	$\geqslant$1,810	(TBD)
Percentage of equipment units in P/M modules	$\geqslant$85	$\geqslant$39

2.5.3 Pallet Design Constraints and Refinement

In the process of performing the feasibility analysis (Task I), various parameters were investigated which could place constraints on the ultimate design of a DCS pallet (e.g., transport capacities, doorway sizes, etc.). In addition, certain features were identified which could be desirable design goals for the pallet. Such parameters and features, resulting from the feasibility analysis, are summarized in Table 2-21.

The constraints and features shown in Table 2-21, along with the simple pallet concept used to demonstrate feasibility, were used as the starting point for refinement of the pallet design in subsequent tasks. The design refinement and the results are described in Annex A to this report. In that annex, each of the pallet engineering considerations cited in the SOW is discussed, the rationale for design conclusions is described, and design recommendations are presented. Once those characteristics were defined, within the bounds of the constraints in Table 2-21, a series of discussions was held with metal fabricators, material suppliers, and other C-E

TABLE 2-21. DCS P/M CONCEPT DESIGN FACTORS

The following criteria, taken from Tables 2-3, 2-5, 2-17 and reference specifications, are representative of some of the factors considered in the iterative approach to the initial pallet design.

Transport Factors:

Size	(1)	78 inches H 84 inches W 222 inches L	Internal carriage in CH-47 B/C and CH-54 A/B helicopters
	(2)	72 inches H 76 inches W 196 inches L	Internal carriage in M291A2; M292; M313 Expandable vans and semi-trailers
Weight	(1)	5,000 lbs (cross-country)	M292; M820 truck vans
	(2)	6,000 lbs (cross-country)	M348A1 and A2 semi-trailers
Airlift	(1)	84 x 50 inches (load surface)	463-L Type II pallet
	(2)	84 x 101 inches (load surface)	463-L Type I pallet

Facility Factors:

Doors	(1)	69 inches H 60 inches W	ISO-1-C, shelter, rigid, JOCOTAS
	(2)	72 inches H 48 inches W	Nominal standard for Mil. C-E trucks, vans, semi-trailers
	(3)	96 inches H 48 inches W	AT&T new equipment building stds (NEBS)
Aisles	(1)	42 inches W (front access)	MIL-STD-1472
	(2)	54 inches W (front access)	AT&T/NEBS
	(1)	30 inches W (rear access)	TM-11-486
	(2)	24 inches W (rear access)	AT&T/NEBS

Note: Clearance requirement to move pallets down aisles and turn to insert into equipment bay locations = 1.1 x pallet diag. msmt.

Floor Load	(1)	150 lbs/sq. ft.	CCTM-105-50-6 (facilities)
	(2)	600 lbs/4 sq. ft.	Shelters, vans, semi-trailers

Equipment Factors:

Racks	(1)	84 inches H 21 inches W (max) 22 inches Deep (max)	MIL-STD-189 racks (for 19-inch and associated panels)

TABLE 2-21. DCS P/M CONCEPT DESIGN FACTORS (Cont)

<u>Equipment Factors</u>: (Cont)

Cabinets	(1)	58.5 inches H 22.0 inches W 26.0 inches Deep	Example of commercial item; no standard military or commercial model in general use
	(2)	12, 18, or 24 inches deep	AT&T/NEBS recommendation
	(3)	DEB upgrade equipment compatible with 57-inch cabinet height.	
Lifting Eyes (Removable)	(1)	3 inches H (on cabinet top)	MS-51937 supports 4000 lbs
Weight	(1)	950 lbs (max)	DEB/MEP power supply
	(2)	455 lbs (max)	AN/FRC-62 radio
	(3)	262 lbs	Alarm monitor group rcvr
Misc.	(1)	Guard rails ∠2 inches from panels	AN/FRC-170 series spec'n (DRAMA)
	(2)	Operate without use of blowers; forced air	AN/FRC-170 series spec'n (DRAMA)
	(3)	Lightweight pallet construction for ease of handling blank pallets.	
	(4)	Forklift handling capability built-in	
	(5)	Modules readily installed in or removed from equipment bays without disrupting cable runs at site	
	(6)	Minimal pallet production costs	
	(7)	Minimal transition costs (module assembly, site adaptation, interoperability)	

pallet users. These discussions identified design options and cost sensitivities and served to gather a consensus of recommendations regarding materials, construction techniques, structural requirements, cost drivers, etc.

As a result of these discussions and recommendations, an initial pallet design was developed and submitted to several manufacturers for costing. Several further minor modifications to the structure were made, based upon manufacturers' suggestions for reducing cost. The final resultant pallet design concept is shown in Annex A, Section 1.2. It is presented there (and also shown at the start of Chapter 3 of this volume) in a form which was considered most useful for future studies or concept development, and represents an optimum mix of all options considered.

The pallet design shown in Annex A and used for the final cost estimating is by no means claimed to be the only acceptable design, nor is it demonstrably the optimum design. The final design for such a pallet should be the result of a detailed design, structural, and fabrication analysis by one or more qualified manufacturers. However, the design concept developed in Annex A and used in Chapter 3 is considered to be adequately close to a final design for the purposes of this study, in that it:

a. Satisfies the constraints of Table 2-21.

b. Reflects our rationale and best engineering judgment associated with the 25 engineering and design considerations cited in the SOW.

c. Provides a suitable pallet structure for the DCS equipment identified for this study.

d. Provides all of the design features and capabilities which can be shown to be definite requirements based upon specific data available to this study.

e. Reflects the combined judgment of ARINC Research study personnel, industrial metal fabricators, and other C-E pallet users.

f. Provides a specific design for cost estimating, which is believed to be reasonably and usefully close to a thoroughly engineered design solution.

Selection of the pallet design in Annex A does not preclude the possibility that a larger pallet would provide a preferable solution if some of the constraints were altered by different deployment or employment concepts in the future. Further, the continuing reduction of electronic equipment sizes which may be anticipated in the 1990s time frame, coupled with any new DCS network concepts in that decade, could result in considerably higher levels of factory preassembly and integration than indicated in this chapter. The resultant increase in module functional complexity and decrease in number of modules per site would further enhance the desirability of the P/M concept.

Chapter 3
COST DATA EVALUATION FOR P/M CONCEPT

This cost data evaluation task assesses the economic implications of the palletization/modularization concept. The first part of this chapter presents the results of a survey of several potential fabricators of pallets as shown in Figure 3-1. Included is an estimate of the pallet production costs in quantities of 100, 500, 2,000, and 10,000. Also addressed are the sensitivities and risks associated with the production cost estimates.

The second part of the chapter presents the economic implications of the P/M concept versus present conventional deployment methods for two selected transition scenarios. Also included are the potential cost drivers and time savings of each concept approach (P/M versus conventional), and a qualitative discussion of other factors that may impact the life cycle cost of the P/M concept.

3.1 PALLET PRODUCTION COSTS, SENSITIVITIES, AND RISKS

This section describes the results of interviews with current users of palletization concepts and potential fabricators of a representative pallet. Detailed production cost estimates for a pallet are presented in lot quantities of 100, 500, 2,000, and 10,000. The cost sensitivities of the estimate are addressed with respect to design features of the pallets. Finally, an assessment is made of uncertainties associated with the cost of materials, and manufacturing labor; manufacturing techniques; manufacturer financing of materials; and type of contract for the production run.

3.1.1 Survey of Current Users of Palletization Concepts

To obtain representative costs for implementation and use of the P/M concept, a brief survey was performed of current users of similar concepts. The survey revealed that the concept is generally accepted in both industry and the government as viable and economic in those instances where electronic equipment is moved frequently (i.e., at least twice annually and requires considerable integration and assembly (i.e., 20 to 25 man-days) to achieve operational status.

One such commercial user interviewed was the Commercial Systems Division of the Space and Communications Group, Hughes Aircraft Company. Within this division, the Satellite Ground Systems Laboratory has fabricated selected test systems and special ground equipment onto large, customized pallets for rapid deployment throughout the world. No production cost for these pallets, nor the cost savings realized by using the concept, could be obtained. However, significant savings in both cost and time were claimed by Hughes in packaging and shipping, assembly, installation and checkout on site, and wear and tear on the equipment. Under this concept, the equipment is operational in a matter of hours, in lieu of days as in the conventional method.

A second user of a palletization concept is the Litton Ships Division of Pascagoula, Mississippi. This division assembled and integrated a Combat Information Center on aluminum pallets to facilitate subsequent installation on DD-963 class ships. As in the example above, the pallets were custom fabricated to accommodate several different

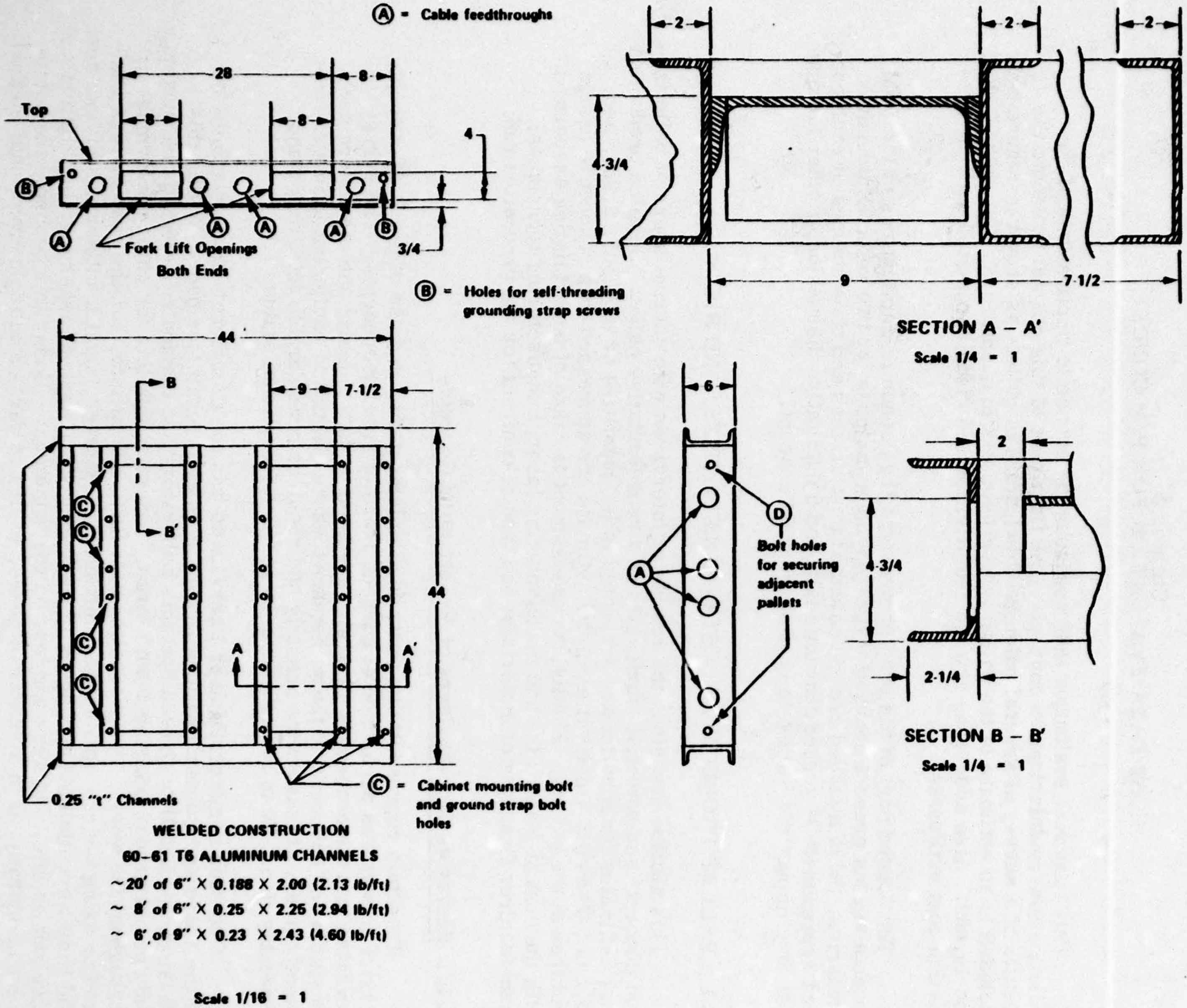


Figure 3-1. Proposed Pallet for DCS Palletization/Modularization Concept

types of electronic equipment. These large pallets essentially eliminated the task of assembly, installation, and checkout on board the ships. Again, no data are available to quantitatively assess either the economic or time savings of this approach. It has been learned, however, that one disadvantage of the concept became apparent when the installation of the equipment was significantly delayed due to delays in ship construction. During this period, several modifications were requested in the equipment on the pallets, necessitating their frequent removal from storage and subsequent disassembly. The requirement to disassemble the equipment for each modification increased its cost over that which would have been incurred for equipment stored in a disassembled state.

3.1.2 Survey of Potential Fabricators

A survey was performed to identify representative metal fabricators in the area of Los Angeles who potentially could produce a pallet. Capable fabricators are located throughout the United States — and those in the Los Angeles area were chosen for this study due to schedule and funding constraints. These fabricators included:

a. Craig

b. Goldsworthy Engineering, Inc.

c. ALL-BANN Enterprises, Inc.

d. Thiem Industries

Within the Los Angeles area, these fabricators were selected since they represent a cross-section of industry from small, privately owned shops to large factories. All have performed contracts for the government, possess the capability to fabricate at least 100 pallets per month, and are experienced in a variety of metals (although Goldworthy deals solely in fiberglass).

Interviews were conducted with representatives of the above manufacturers, and facility tours were conducted where possible. During each interview an attempt was made to determine the availability and applicability of cost estimating relationships (CERs) for pallet manufacturing, or costs for similar pallets. Responses to these questions are discussed in Section 3.1.3. Also during each interview, the manufacturers were requested to provide a detailed cost breakdown for the production of pallets (fabricated in accordance with the design outlined in Task 2) in quantities of 100, 500, 2,000, and 10,000. Further, with respect to their estimate, each fabricator was requested to identify the sensitivity of production costs to the design features of the pallet, the use of various metals, alternative manufacturing techniques, production techniques as a function of production quantities, and learning curves and rates. Finally, the interviewers were requested to identify any risks they foresaw in the production of such pallets. Results of these interviews are discussed in Sections 3.1.3 through 3.1.6.

3.1.3 Survey of CERs/Costs for Similar Pallets

Both Craig and Thiem Industries have manufactured customized aluminum pallets for either industry or the government. However, representatives of both firms expressed the belief that such costs, if researched and analyzed, would not be representative of the suggested pallet design for the DCS P/M concept. Further, none of

the manufacturers interviewed were aware of any cost estimating relationships (CERs) for pallet manufacturing. Finally, an independent literature search failed to reveal any representative costs or CERs other than for standard wooden pallets or metal dollys. All prior metal pallets were custom designed for a specific installation/deployment concept, and were purchased in relatively small quantities; and little or no data were retained that would permit the development of a representative CER.

3.1.4 Pallet Production Costs

As described in Section 3.1.2, each firm interviewed was requested to provide a detailed estimate of the production cost of various quantities of pallets. It is noted however, that an estimate from Goldsworthy Engineering would not be representative since that company fabricates exclusively in fiberglass, and it appears that using this material in the pallet, as currently designed, would not provide sufficient structural strength.

3.1.4.1 Pallet Production Cost Estimate

Table 3-1 presents a composite of the manufacturers' estimates for quantities of 100, 500, 2,000, and 10,000 pallets at a production rate of 100 per month, using 1979 costs. The cost categories are as follows:

a. Total Material – This cost category includes the total unit cost of raw material, purchased parts, and outside production and/or processing. Calculated based on actual costs for the representative pallet design.

b. Direct Labor – Includes the total unit cost of setup, machine shop, fabrication, welding, assembly, and other labor-related costs. Estimated based upon a total number of hours multiplied by the rate for each of the above steps.

c. Labor Burden – Reflects a factor for overhead. Calculated as a percentage of the total direct labor (item b).

d. General and Administrative (G&A) – Includes expenses related to the overall business costs such as staff services. G&A is calculated as a percentage of the total factory cost (total of a, b, and c above).

e. Profit – The fee a manufacturer receives to perform the contracted functions. Profit is calculated as a percentage of the sum of the following costs: total factory cost (sum of a, b, and c) plus G&A (item d).

f. Tooling – Includes the total direct cost of unique tooling required to perform any contracted production run such as special dies or test equipment.

g. Total Production Cost – Includes all costs associated with the performance of the contracted production run (items a through f).

The above costs are freight-on-board (FOB) at the factory. Therefore, distribution of the pallets, once fabricated, would be in addition to the above. The above

TABLE 3-1. PALLET UNIT PRODUCTION COSTS

Cost Category (See Sect. 3.1.4.1)	Cost ($) per Unit for Indicated Production Quantity			
	100	500	2,000	10,000
Direct material	119	112	105	102
Direct labor	89	83	82	77
Labor burden (176%)	157	146	144	136
Total Factory Cost	365	341	331	315
G&A (18%)	66	61	60	57
Total Cost	431	402	391	372
Profit (17.5%)	75	70	63	65
Lot Size Unit Manufacturing Cost	506	472	459	437
Tooling	$7,650			
Total Production Cost	58,250	243,650	925,650	4,377,650
Pallet Unit Production Cost	582.5	487.3	462.8	437.8

costs include all structural members to support the weight of C-E equipment in racks, and forklift access from two sides. The cost does not include:

a. Mounting attachments/fittings for securing one or two racks. This cost was excluded since it is envisioned that the activity that assembles the C-E equipment on the pallet would drill the appropriate number of holes and secure the racks using nuts, bolts, and washers.

b. Fittings to join adjacent pallets. This cost was excluded since the pallets can be joined by on-site installers using long bolts with necessary nuts and washers.

c. Fittings for leveling devices or wheels. This cost was not included since leveling can be easily accomplished by on-site installers using a separate level and shims. Further, fittings for wheels were not included since movement can be accomplished by on-site installers either with forklifts, dollys, or hand-driven hydraulic lifters such as "Pallet-Master".

d. Tie points or mounting fixtures for in-transit securing to shipping pallets. This cost was also not addressed since it appears that the modules can be secured to shipping pallets with the usual straps or nets now used by transportation organizations.

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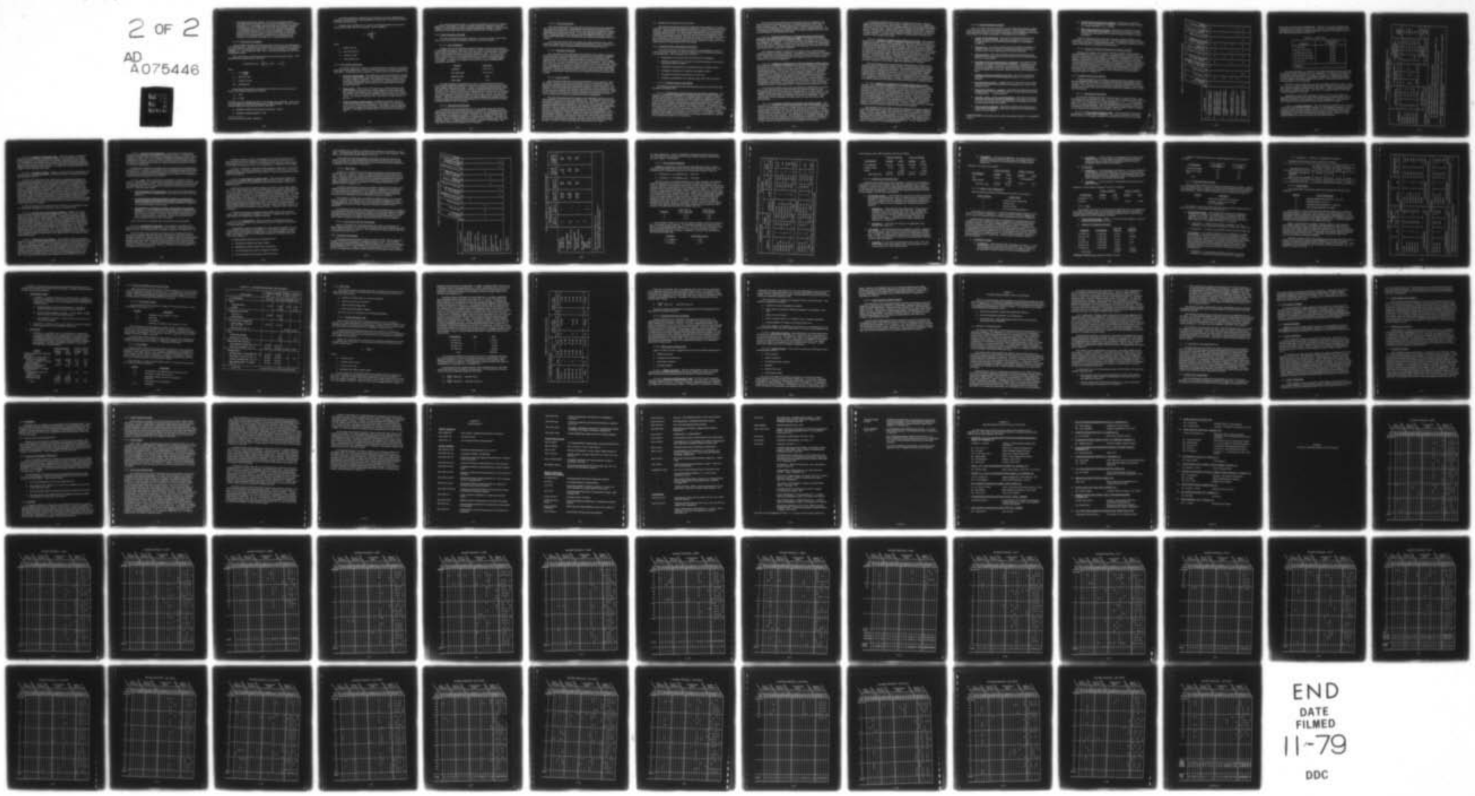

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e. **Appropriate top surface material.** The cost of covering the pallets is more appropriately included in the cost element "Integration and Assembly" in Section 3.2. It is expected that the flooring will be added to the pallet by the assembler of the equipment once he has determined the optimum C-E equipment surface area (e.g., one or two cabinets of equipment) versus the pallet surface area. All potential fabricators of the pallets stated that they would not produce a cover for the pallet and that such a process is more appropriately accomplished by a manufacturer who specializes in false-floor coverings (e.g., computer facility floors).

3.1.4.2 Pallet Unit Cost Equation

Using the above estimates, the theoretical first unit cost (T_1) and learning rate (LR) were calculated. It should be remembered that the above statistics are estimates and should not be considered as precise values. Since the variables are continually changing (i.e., cost of materials, labor, etc.), any derived learning rate can be only an approximate value.

The T_1 and LR were estimated using the unit cost learning curve theory.* The following standard approximation was used:

$$\text{Average Unit Cost} = \frac{T_1}{NX}\left\{ (N-0.5)^x - (0.5)^x \right\}$$

where

$$x = \frac{1 + \ln(LR)}{\ln(2)}$$

T_1 = first unit cost

N = number of units

LR = learning rate

Using the pallet production cost estimates of Table 3-1 for lots of sizes 100 and 500, the following results were obtained:

T_1 = \$839

LR = 0.9723

The above LR value indicates that little or no learning can be expected. Such a value can be anticipated in manufacturing processes of little complexity. The LR value is somewhat higher than the following industry experience:

a. Repetitive machine or punch-press operations: 90-95%

b. Repetitive welding operations: 90%

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*NASA Tech Memo X-64968, Appendix A.

Care should be taken in using the above values of T_1 and LR in estimating the production cost of pallets for various quantities of pallets due to the potential escalation of material and labor costs.

Using the above statistics for T_1 and LR, the following equation can be used to estimate the average unit cost of a specific number of pallets:

$$Y = \frac{A}{N} \sum_{i=1}^{N} i^b$$

where

Y = dollars per unit

A = first unit cost (T_1)

N = number of units

b = learning rate (LR)

3.1.5 Pallet Design Sensitivities

To minimize pallet costs, details of the pallet design were iterated several times based upon design suggestions received from both current users of pallets and potential fabricators. Among those features changed as a result of these recommendations were:

a. Aluminum channel height. The height of the aluminum channels was reduced from 8 to 6 inches without adversely affecting the overall structural strength or weight capacity of the pallet. This change resulted in a reduced cost of materials of approximately $115 to $130 per unit, depending upon the quantity of pallets purchased; and lowered the cost of direct labor for welding by about $5 per unit.

b. Pallet corners. The corners of the pallets were initially illustrated with picture-frame (mitered) corners. At the suggestion of those interviewed, this approach was changed to reflect butted corners, as this would reduce direct labor costs for riveting and assembly while providing a more finished corner. This change reduced the cost of direct labor by approximately $5 per unit.

c. Welded construction versus rivets. In addition to the above, the use of rivets in the construction of the pallets was eliminated in all fabrication areas in favor of all welded construction. This change, while not affecting the structural strength of the pallet design, minimized the direct labor for assembly. This change also reduced the cost of direct labor about $5 per unit.

As a result of the above efforts, it is felt that the pallet as currently configured represents a cost-effective concept, and further significant reductions in cost are unlikely. Any added features such as mounting attachments, fittings, or fixtures would increase the direct labor costs while adding a minimal cost in direct materials.

3.1.6 Pallet Production Cost Risks

The risks of the pallet production costs are in four major areas: cost of materials, cost of direct labor, financing of materials, and type of contract.

3.1.6.1 Cost of Materials

Perhaps the most unpredictably fluctuating variable is the cost of the material for the pallet construction. Most metal costs are subject to market supply and demand, and this appears especially true of the cost of aluminum. Since aluminum is increasingly in short supply, the demand essentially dictates the price. At any one point in time, the cost per foot of 6-inch channel aluminum may exceed or be cheaper than 8-inch channel. However, the market price for steel, wood, or fiberglass appears more stable. Currently, the average cost per pound for various candidate pallet construction materials is:

Material	Cost ($/lb)
Aluminum	0.985 to 1.08
Hot rolled steel	0.26 to 0.32
Stainless steel	2.00
Fiber glass	1.00

The pallet production cost assumes the use of 6-inch channelized aluminum. Most aluminum suppliers contacted were extremely reluctant to provide a fixed quote with an effective date beyond 30 days. Further, each potential pallet fabricator stated that either their contract would have to include an escalation clause for the cost of materials, or the material would have to be purchased by the government and furnished to the fabricator as government-furnished material (GFM). Finally, the cost of aluminum can be expected to increase monthly at a rate at least equal to or greater than inflation. Due to this expected increase, the pallet production cost estimate should be revised to reflect the current cost of materials prior to any final decision concerning the implementation of the P/M concept.

3.1.6.2 Manufacturing Techniques

As detailed in the preceding section (3.1.5), the pallet design was iterated to reduce not only the cost of materials but also to optimize the manufacturing process. The analysis of the fabricators' estimates reflected that minimal learning would occur as the quantity of production increased. Therefore it is concluded that the pallet production costs are essentially insensitive to manufacturing techniques. The pallet, as a design, requires minimal welding and assembly. The only design feature that might affect the process is a tightening of the tolerances specified in the drawing. This would tend to increase the production cost of the pallet.

3.1.6.3 Cost of Direct Labor

The cost of direct labor can be expected to increase but not at the accelerated rate of the cost of materials. Manufacturers interviewed advised that the rate of direct labor (currently $6 per hour in the area surveyed) can be expected to increase approximately one percent per month. Due to this anticipated growth in the cost of labor, the pallet production cost estimate should be updated to reflect the current cost of direct labor prior to any final decision concerning implementation of the P/M concept.

As for the other factors that may impact upon pallet production costs, manufacturing overhead was found to vary among those interviewed. Such overhead is, by itself, a function of many variables and often fluctuates throughout the year.

3.1.6.4 Financing of Materials

Due to the above cost of materials and the relatively large quantity of material needed to produce several thousand pallets, fabricators were reluctant to capitalize the purchase of the aluminum. Such a purchase for a large manufacturer (300-employee shop) would tie up a substantial amount of funds and may adversely impact their cash flow. For small manufacturers (less than 50 employees), such a purchase could not be pursued due to the lack of capital or ability to finance the material. Therefore, depending upon the quantity of pallets specified in any one contract, competition among manufacturers to fabricate the pallets may be limited to only the larger manufacturers. Consideration should be given to various means which either assist fabricators in the financing of materials or have the materials provided by the government as GFM.

3.1.6.5 Type of Contract

Due to the above-mentioned risks associated with the cost of materials, labor, and ability to finance the purchase of aluminum, the type of contractual vehicle and procurement approach used to acquire the pallets must be carefully considered. All fabricators interviewed expressed reluctance to respond to a Firm Fixed Price (FFP) contract. The only contract that would be considered was one that includes provisions for the financing of material and escalation clauses for both material and labor. Therefore the type of contract should be carefully assessed by procurement specialists in order to reduce the risk both to the government and the manufacturer.

The procurement approach and structure of the solicitation should also be carefully considered in order to reduce any potential risk. All fabricators interviewed are accustomed to standard cost proposals (Form DD 633), based upon a review of a build-to-drawing submitted by the government. However, few if any manufacturers would apparently respond to both a technical and cost proposal solicitation that required them to further iterate the design of the pallet and to cost these various design options. Moreover, it appears that most would be reluctant to voluntarily participate in an open forum to iterate the design of the pallet and discuss the ramifications of various manufacturing techniques. Finally, fabricators interviewed stated that they would only consider a contract in which the total cost of labor (direct labor cost plus labor burden) exceed the total cost of material. However, risk in this acquisition area is low since it is unlikely that the material cost would exceed labor costs unless either the type of contract or procurement approach minimized the cost of labor.

3.2 TRANSITION SCENARIO COST ANALYSIS

This section assesses the economic implications of the proposed P/M concept versus the current conventional deployment concept for various hypothesized transition scenarios. The scenarios are defined, including the identification and description of activities dictated by each. Two representative transitions are then selected which encompass all activities and are used to estimate the economic implications of the P/M versus conventional concepts. Both the cost drivers and the differences between the two concepts are summarized, along with the potential time savings. Finally, other costs not inherent in the transition periods are qualitatively assessed to reflect potential life-cycle implications of the P/M concept.

3.2.1 Transition Scenario Description and Selection

To provide a baseline from which to assess the cost implications of the P/M versus conventional concepts, six typical transition events and supporting scenarios were hypothesized. These transitions are as follows:

a. Replacement of a terminal with a new generation of equipment.

b. Deliberate relocation of C-E assets of a small fixed station site from one permanent location to another.

c. Contingency establishment of a small DCS station in another country.

d. Contingency relocation of a small site into another country.

e. Foreign government-forced closure of a major site.

f. Deliberate consolidation of two separate major sites into one location.

3.2.1.1 Transition Scenario Descriptions

The following paragraphs describe the assumed scenario for each of the above six typical transition events.

3.2.1.1.1 Replacement of Terminal with New Generation of Equipment. This transition constitutes the upgrading of an existing European DCS station, replacing outdated analog equipment with DEB IV and DRAMA-generation digital equipment. For the sake of analysis, the upgraded Frankfurt equipment configuration is assumed to be the resultant site after the transition. It is further assumed that the upgrade equipment merely replaces existing analog equipment providing similar station capability, and does not represent a change of the station capability. The upgrade does not require a relocation of the station to a new location, and for the sake of the analysis it is assumed that no new facility construction is required at the station. (If new facility construction were required, the choice of current versus P/M deployment concept would have little impact on construction cost. Section 2.3.1.5 of Chapter 2 indicated that floor space inefficiencies related to the P/M concept could be held to a minimum level at sites where space was at a premium.)

It is assumed that the schedule for this transition type is not pressing, with ample advance notice allowing an orderly, well planned transition rather than an urgent contingency effort. Existing equipment to be replaced at the site will be recovered and brought back to CONUS for salvage or use as surplus equipment. The C-E equipment and upgraded site capability will be identical, whether current or P/M concept deployment and installation are used.

3.2.1.1.2 Deliberate Relocation of C-E Equipment Assets of Small Fixed Station Site from One Permanent Location to Another. This transition constitutes an orderly, well planned move of a small site, without any change in site communication capabilities or equipment. It is assumed that some predictable economic or policy criteria lead to the relocation, and that the new location will require the establishment of a new DCS facility. The nature of the small site equipment is assumed to be represented by the FKV II equipment at Melibokus.

The transition schedule is presumed to be nominal, with no unusual urgency imposed by tactical or political conditions. No equipment or facilities will be returned to any location other than the intended new station site, either for salvage or refurbishment. There will be no difference between site equipment in the P/M case and site equipment in the current configuration.

3.2.1.1.3 Contingency Establishment of Small DCS Station in Another Country. This transition constitutes the establishment of a new DCS capability at a location not previously used as a DCS site of any type. The equipment and capability to be provided at the new site is assumed to be that shown in Table 3-12 for the Type II DCS reconstitution package. The new site will be housed in transportable, expandable shelter structure(s) such as the ISO 8 x 20-foot shipping container. In the P/M configuration, the contingency site equipment would be preassembled and stored at some U.S. controlled facility in the other country in which it is to be deployed. Deployment and installation/activation will be preplanned as a matter of tactical preparedness, and trained deployment teams will be available on short notice. In the non-palletized configuration, C-E equipment will be stored in a nearly operational configuration within a transportable shelter, requiring minimum setup time on site.

It is assumed academic what events necessitated the establishment of the site, but it is also assumed that the deployment does not require the removal of any damaged equipment nor any unusual site preparation due to a conflict situation. The schedule for site deployment is assumed to require full site activation within 1 week (7 days) of the time at which the requirement for the site is established. Contingency package mission objectives also state a goal of 2 hours for on-site setup and activation.

3.2.1.1.4 Contingency Relocation of Small Site into Another Country. This transition is the removal of a small operating station (Type II reconstitution package) housed in a transportable shelter in a foreign country, the transport of the station to a new location in a different country, and the reactivation of the station in a transportable shelter at the new site. Neither the previous nor the new site is co-located with any other DCS facility. There is no change in the station capabilities nor equipments as a result of the transition. Since the station is a contingency package, the procedures for removal, transport, and redeployment are assumed to be planned in advance, with only local logistic factors to be planned uniquely for the transition. Trained removal and deployment teams will be available on short notice.

It is assumed irrelevant what events necessitated the transition, although a change in tactical situation is a likely cause. Neither the removal nor redeployment require the removal or repair of any damaged equipment, and no unusual site preparation tasks are necessary. Neither removal nor redeployment take place under local conflict conditions, which would present a physical danger to the crews or equipment. However, the urgency to remove and redeploy the station is assumed to be driven by a conflict situation, so that the need to minimize transition time is critical to the support of force command and control.

3.2.1.1.5 Foreign Government-Forced Closure of Major Site. This transition, assumed to be required by a change in diplomatic relations or a policy decision of a foreign government, requires the disassembly and retrieval to CONUS of a major DCS station currently operating at a permanent facility. The transition is not considered to include any restructuring of the DCS or establishment of a new station to replace the one removed. Such activities, while perhaps a necessary result of the site closure, are defined to be beyond the scope of the site transition described here. It is assumed that the permanent facility itself is abandoned after the DCS equipment has been removed. In removing the station, all possible DCS equipment is to be saved and returned to CONUS in good condition. Minimal equipment damage is desired, so that the equipment can be redeployed elsewhere with minimum refurbishment expense. The site is assumed to be the DEB IV upgraded configuration at Frankfurt.

The events leading to the site closure allow approximately 2 months advance warning to plan and complete the station removal. No open hostility exists, and the foreign government is generally cooperative in allowing personnel access and transport provisions as required for site closure. The DCA has considerable flexibility in how it chooses to schedule the removal, with the one constraint that no station capabilities can be deactivated until 7 days prior to the completion of the closure. Prior to that time, full station services must be maintained in order to support other U.S. operations in the foreign nation. Further, a capability for at least 25 percent of the station channels must be kept active until three days prior to complete closure.

3.2.1.1.6 Deliberate Consolidation of Two Separate Major Sites into One Location. This transition is assumed to be a part of the implementation of a significant upgrading of the network configuration of a portion of the DCS. The consolidation requires the closure of two existing major stations, both in permanent facilities, and relocation of major portions of their equipment to a single new permanent facility. The capabilities and equipment configuration at the new site are not simply the sum of the two existing sites, but represent a totally new station. Maximum use will be made of existing equipment at the two current sites, however, since the transition does not include an upgrade to newer generations of C-E equipment. Some limited amount of new equipment will be deployed from CONUS to provide capabilities or capacity not available at the two current sites. Likewise, a limited amount of existing equipment will be returned to CONUS for salvage or use elsewhere.

The transition will be the result of long-term planning and strategic upgrading of the DCS configuration, and as such will not be conducted on an urgent contingency basis. However, undue delays in the transition are to be avoided because of the disruption of service caused by the transition. To the extent possible, an incremental transition will be planned, allowing partial service by the existing stations until at least partial service is attained at the new consolidated site. The transition will not make use of any contingency or reconstitution equipment. The new station will require construction of a new permanent facility.

3.2.1.2 Transition Scenario Activities

Each of the above-identified transitions and their supporting scenarios suggest various activities that occur during these transitions. These activities are discrete events that expend manpower and material resources at a rate dependent on the deployment concept (P/M versus conventional). The activities are as follows:*

1) Conduct on-site engineering. This activity includes the prior planning, enroute, on-site, and return expenditure of manpower resources to evaluate the physical and electrical characteristics of a new proposed installation.

2) Plan the move. This activity includes that administrative expenditure of manpower resources to prepare a contingency/transition plan in those instances where on-site engineering is not deemed necessary.

3) Plan the cutover. This activity entails that prior engineering planning necessary to accomplish the electrical transition from one communication service or link to another.

4) Assemble and test new equipment prior to shipment. This activity is that expenditure of manpower and material resources by a manufacturer associated with the design, development, and production of mating surfaces, structures, equipment, parts, and materials required to assemble and test all equipment into an installed, operational entity at the manufacturers' plant.

5) Package equipment for shipment to new site. This activity includes the expenditure of resources during packing, handling, and crating prior to shipment.

6) Ship equipment to new site. Includes the use of resources to move equipment from one point to an operational site using land, sea, and air transportation modes.

7) Disassemble existing site equipment. That effort necessary to break down equipment being removed to a level sufficient to permit subsequent packing and shipment from the operational site.

8) Assemble, install, and test new site equipment. This activity includes all materials and services required for placement and assembly of the equipment in the site facility, and complete checkout of the equipment to ensure its achievement of operational status.

9) Cutover new site equipment. This activity includes that physical reconnection effort accomplished to effect the transfer from one communication service or link to another.

*In the discussion, a site facility may be either a permanent structure or transportable shelter.

10) Package existing equipment for shipment. This activity is identical to item 5, above, except that the equipment is destined for return to CONUS for eventual disposition (e.g., salvage).

11) Ship existing equipment to storage. This activity is identical to item 6, above, except that the equipment is intended to be returned to a CONUS destination for disposition rather than to be utilized at another overseas site facility.

Table 3-2 illustrates which of the above described sctivities typically occur during any or all of the transition scenarios. The six transitions are listed vertically and the above activities are presented horizontally. A checkmark indicates the occurrences of that activity in a specific transition scenario.

3.2.1.3 Selection of Transition Scenarios for Economic Analysis

Based upon an analysis of the matrix of activities related to each transition scenario displayed in Table 3-2, Transition A (Replacement of a terminal with a new generation of equipment) and Transition C (Contingency establishment of a small DCS station in another country) offer complete coverage of all activities while allowing analyses of both fixed and transportable sites. Further, the selection of Transition A will permit the analysis of in-plant assembly of site equipment for P/M versus current concept comparison (Activity 4), and are expected to provide an unbiased comparison of P/M versus current techniques. It should be noted that Transition A includes all activities with the exception of Activity 2, which will be addressed in Transition C. The salvage value of retrieved equipment will be addressed as a separate factor within the context of Transition E.

3.2.2 Transition Activity Cost Elements

To address properly the cost elements associated with each transition activity, the cost estimating methodology, as prescribed by Defense Communications Agency Circular (DCAC) 600-60-1, was used to assess the economic implications of the two concepts. The cost elements were structured as presented in Figure 1 of the circular. The structure of costs below these cost elements followed the direction of this circular wherever possible.

3.2.2.1 Cost Element Descriptions

The following describes each cost element in Figure 1 of DCAC 600-60-1, and the approach used in estimating its value. Any cost data not available in DCAC 600-60-1 were sought from the contract COR; ECOM Pamphlet 11-4, Vol. 7, Cost Estimating Guide; U.S. Army CORADCOM Cost Estimating Handbook; or the Army Comptroller's Army Force Planning Handbook. Data not available from those sources in time to be incorporated into the study effort were estimated, based on ARINC Research judgment, or were deleted from consideration at the option of the COR.

3.2.2.1.1 Prime Mission Equipment (PME). This cost element includes the acquisition cost of major items of equipment. The scenario definitions have stated that the actual C-E and support equipment to be deployed at DCS sites will not differ

TABLE 3-2. TRANSITION SCENARIOS/ACTIVITY MATRIX

Transition Title	1. Conduct on-site engineering	2. Plan the move	3. Plan the cutover	4. Assemble & test new equip. prior to shipment	5. Package equip. for shipment to new site	6. Ship equip. to new site	7. Disassemble existing site equip.	8. Assemble, install, & test new site equip.	9. Cut over new equip.	10. Package existing site equip.	11. Ship existing equip. to storage
A. Replacement of terminal with new generation of equipment	X		X	X	X	X	X	X	X	X	X
B. Deliberate relocation of C-E equipment assets of a small fixed station site from one permanent location to another		X			X	X	X	X			
C. Contingency establishment of a small DCS station in another country		X				X		X			
D. Contingency relocation of small site into another country		X			X	X	X	X			
E. Foreign government-forced closure of a major site		X					X			X	X
F. Deliberate consolidation of two separate major sites into one location	X		X		X	X	X	X	X	X	X

between the P/M and current configurations. Therefore, no mission equipment cost comparisons will be made for the two cases. However, since certain other cost element algorithms are based on equipment acquisition costs, the unit equipment acquisition costs were determined (see Table 3-3).

TABLE 3-3. PME COSTS

Equipment	Unit Acquisition Cost ($)
CY-104/104A	22,000
AN/FCC-97 (8 port)	20,000
AN/FRC-162 (48 Vdc)	48,154
AN/FCC-98 (TD-1192)	21,000
AN/FCC-99 (TD-1193)*	16,500
AN/FRC-170	39,000
*Eight port	

The above cost data are a composite of information obtained from the study COR and from the DRAMA Program Office, Ft. Monmouth. The values are assumed to be average unit procurement costs in Constant FY79 dollars. No attempt was made to revise these unit costs based on any production quantity data, learning curve effects, or future design or technology modifications; however, costs assume sufficient purchase quantities to avoid surcharges.

The above costs are assumed to not include equipment cabinets or racks. Therefore a survey was made of representative unit costs of various size commercially available electronic equipment enclosures and relay racks. Table 3-4 presents the results of the survey of cabinet/rack costs. Also shown is a standard cabinet for utilization in implementing the P/M concept.

Acquisition of racks will be compared for the P/M versus conventional configurations based upon the above data, their extrapolation for smaller racks, and any differences identified in rack quantities for the two configurations. Rack quantities and dimensions were determined from data already presented in Chapter 2.

3.2.2.1.2 Auxiliary Equipment. This cost element is defined by DCAC 600-60-1 to include the cost of electric power, modems, and cryptographic equipment. No cost analyses for these items were performed since 1) it is assumed that electric power generating and conditioning equipment will be identical in the P/M and conventional configurations, and 2) the cost manual does not contain data on modems or cryptographic equipment nor does it provide cost estimating techniques.

TABLE 3-4. PME CABINET/RACK DIMENSIONS AND COSTS
(Dimensions in inches, costs in dollars)

Equipment	Equip. Dimensions			Present Cabinet/Rack Dimensions			Conventional Representative Cabinet/Rack Dimensions			Cost/Rack Cost[2]
	H	W	D	H	W	D	H	W	D	
CY-104	36	19		48	23		46	22	25-7/8	245
AN/FCC-97	39	19	12				46	22	25-7/8	245
AN/FRC-162	45	19		66	24	26	66	22	25-7/8	2,800[3]
AN/FCC-98	193	19	20	23	19		27	22	25-7/8	198
AN/FCC-99	24	19	20				37-1/2	22	25-7/8	214
AN/FRC-170	74	19		84[1]	21	25.3	77	22	N/A	70
	P/M Panel Space						P/M Std. Cab. Dimensions			Std. Cab. Cost
P/M Concept	52-1/2	19	23				58-1/2	22	25-7/8	265[4]

Notes: (1) Self-supporting channel-type rack

(2) Represents composite unit cost in large-quantity purchases

(3) Special shielded enclosures (cost based on present cost for 66-inch model provided by COR)

(4) Special shielded enclosures for 58-1/2-inch cabinet assumed to cost $1,665.

Sources: Bud Industries; Dracon Industries; Electronic Enclosures (A. Wyle Co.); Premier Metal Products; Stantron Div. of Wyco Metal Products

3.2.2.1.3 Integration and Assembly (I&A). This cost element, as defined in Chapter 15 of DCAC 600-60-1, refers to the efforts of the contractor to assemble all major equipment and subsystems into an installed, operational system in-plant. It is calculated as a percentage of prime mission and auxiliary equipment acquisition cost. The factors given in DCAC 600-60-1 were used in accordance with engineering judgment and the guidance of that document. No other data or costing algorithms were sought or used to estimate these costs.

3.2.2.1.4 Contractor Training. Chapter 16 of DCAC 600-60-1 breaks this cost into three parts: training (internally) of contractor personnel, contractor training of DCS personnel, and OJT.

To the level of detail found in the DCAC 600-60-1 estimating procedure, no cost differences between the P/M and conventional approaches can be identified for the first two parts of training. The cost estimating procedure for training courses is based on course length, numbers of students in a class, and repetitions of the course. The quantification of these factors is based on reviews of equipment specifications and other pertinent documentation. Since the equipment for the P/M and conventional deployments is identical, no difference in course costs would be expected. While some differences might exist in training DCS personnel in on-site assembly and disassembly, with or without P/M benefits, it is assumed that the differences would be small, with the P/M concept offering lower on-site installation training costs. These cost differences are extremely small compared to other DCS-wide cost elements, and will lie well below the levels of uncertainty that can be justified for cost estimates at this stage of the P/M program.

On-the-job training (OJT) is defined by DCAC 600-60-1 to lie outside the scope of a DCS system or program cost estimate, and is not considered here.

3.2.2.1.5 Peculiar and Common Support Equipment. Chapter 17 of DCAC 600-60-1 breaks this cost into two basic categories: 1) test and common support equipment, and 2) peculiar support equipment. All calculation techniques simply apply a percentage factor to the acquisition costs of prime equipment, with factors varying by program phase. Since the prime mission equipment (and their procurement costs) will be the same for P/M and conventional configurations, application of the DCAC 600-60-1 algorithms would show no cost differences. The possible exception to this result would be support equipment for the pallet itself (e.g., special in-facility hand trucks at a cost of $375 to $400 each, small tools for inter-module attachments at a cost of $2 to $3 each, etc.). The cost difference of such items from normal dolly and tooling costs at a conventional configuration site is considered to be negligible compared to total station cost, upgrade cost, or cost estimate uncertainties at this time.

3.2.2.1.6 System Test and Evaluation. The definition of this cost element in Chapter 18 of the cost manual indicates that the cost is incurred during system development. It is therefore not a portion of any transition scenario cost and will not be considered in comparing transitions. At most, the cost would have to be estimated for the actual pallet design and development and then prorated over the pallet production quantity. The cost manual calls for a test and evaluation estimate of 5% to 10% of prime and auxiliary equipment acquisition costs for systems-type contracts. Since the pallet is not a complex system, a 5% factor would seem appropriate; however, this factor was not included in study cost estimates, at the direction of the COR.

3.2.2.1.7 System/Project Management. These costs are oriented toward development and production management and planning activities. All algorithms in Chapter 19 of DCAC 600-60-1 are based on percentages of acquisition costs, with the exception of a dollars/year cost for Federal Contracted Research Centers (FCRC) participation (if planned). Such costs would not tend to occur during site transitions, nor would the cost algorithms indicate any significant differences between P/M and conventional configurations.

Planning for a specific site transition does vary between the two configuration concepts due to the simpler on-site engineering and planning associated with a relocation and cutover. Engineering judgment was used to estimate the relative levels of complexity of transitions in the two configurations and to relate those complexities to project/transition management levels of effort.

3.2.2.1.8 Data. This cost element, as described in Chapter 20 of DCAC 600-60-1, includes the cost of required deliverable data as specified on DD Form 1423, "Contract Data Requirements List". Only those additional data costs associated with the implementation of the P/M concept were considered in the analysis of this cost element. These data costs include:

a. Full data package for the pallet itself. This cost was estimated based on pallet unit costs and the appropriate factors selected from DCAC 600-60-1, Table 20-1.

b. Revised documents regarding installation, checkout, and assembly of current generation DCS equipment (see Tables 3-3 and 3-4) for on-site use. These are added costs due to the P/M concept being applied to equipment for which documentation already exists.

c. Documentation for installation, checkout, and assembly of new DRAMA equipment. It was assumed that a decision regarding P/M implementation was not made in time to appropriately direct DRAMA documentation, and added data costs resulted. It was also assumed that reprocurement data costs are representative of such costs, and they were estimated from prime equipment costs and Table 20-1 factors.

Costs of the above data elements will be prorated across 2,000 pallets.

3.2.2.1.9 Operational Site Activation. Three subsets of operational site activation cost are identified in Chapter 21 of DCAC 600-60-1; contractor technical support (on site); site construction; and assembly, installation, and checkout on site.

The first of these costs addresses contingency types of support at the site, during and immediately after site activation, and aside from the normal (planned) assembly and checkout. While the use of the P/M concept, with its factory assembled and tested modules, is expected to decrease such requirements (fewer critical part shipping delays, lost items, unexpected system problems on site, unplanned field assembly difficulties, etc.), no data were available upon which to base a quantitative estimate of such problem (and cost) reductions. Therefore it was assumed that no cost differences occur in this area.

Facilities construction costs, as discussed in the scenario descriptions, have been assumed to present no significant cost differences between the P/M and conventional approaches. For scenarios involving new facility constructions appreciable cost savings can be expected, e.g., as by eliminations of conduits and cable troughs.

Assembly, installation, and checkout of the equipment at the site is a major cost comparison area. The factors indicated in DCAC 600-60-1, Table 21-3, were used along with equipment unit acquisition costs (Tables 3-3 and 3-4) to estimate the relative costs for this activity.

3.2.2.1.10 Initial Spares and Repair Parts. This cost element includes the cost for initial modules, spare components, and assemblies used for replacement purposes in equipment and is estimated using the factors presented in Table 22-1 of DCAC 600-60-1.

Since the prime mission equipment design and operation will not differ significantly (other than possible assembly of selected items in two cabinets rather than one, etc.) in any aspect which can be identified as impacting reliability, maintainability, or support concept, no rationale can be established for concluding that the P/M concept impacts sparing. Therefore, no cost difference was examined in this area. The only integrated logistics cost requirement would be due to the introduction of new inventory items unique to the P/M concept (i.e., the pallets themselves). Parts sparing for the pallets was assumed to be nonexistent, as they are not a failure item nor does the current pallet concept include detachable parts. Spare parts for support of pallet-unique handling equipment, fixtures, etc., would be a second order cost element, and would lie well below cost estimate uncertainty values. Therefore, their cost was not considered.

Consideration was given to possible small inventory items, such as special cables. Also, the possibility of multiple AN/FRC-170 configurations (single versus dual cabinets) was considered for impact on sparing.

3.2.2.1.11 Transportation. This cost element is described in Section 3, Chapter 24 of DCAC 600-60-1, and addresses the cost (for manpower and material) of transporting things.

Transportation costs were investigated for non-personnel transport only, and were estimated using Tables 24-9 through 24-12. The data were applied as appropriate to the P/M conventional configurations. Prime item acquisition costs were taken from Tables 3-3 and 3-4, and equipment weights were estimated from study Task 1 data (Chapter 2).

Transport phases included in the cost estimate were:

a. Packing and crating at the factory/depot.

b. Shipping from factory/depot to port of departure.

c. Air lift (military) from port of departure to Europe.

d. Local transport costs, Europe airport to DCS site.

Local handling at the CONUS port of departure was assumed to be included in b and c, above. Local handling at the DCS site was assumed to be part of the assembly, installation, and checkout cost element (Section 3.2.2.1.9).

For transitions requiring packaging and crating in the field (at DCS site for station removal), the costs of packing and crating will be assumed to be increased by the same factor as technician pay scales are increased for European assignments, as specified in DCAC 600-60-1, Table 24-15.

3.2.2.2 Other Costs

Section 3.2.2.1 addressed all of the system acquisition cost elements defined in DCAC 600-60-1, Figure 1. Figure 2 of that manual defines annual O&S cost elements. However, such costs are part of neither the pallet unit procurement cost nor DCS site transition costs, and are therefore not addressed quantitatively during this study. Identification of selected O&S cost considerations and discussions of their expected qualitative behavior as a function of P/M concept implementation are addressed herein in Section 3.2.5.

A review of the activities listed in the transition scenario matrix indicates that certain additional costs must be considered to obtain a satisfactory comparison of P/M and conventional configurations. One significant transition cost not provided for in the above cost element is the salvage (residual) value of existing equipment recovered or lost during the forced or contingency removal of a station.

The residual or salvage value of existing DCS equipment lost at, or recovered from, a closed site was estimated for P/M and conventional configurations of that existing equipment. The residual values were determined according to the algorithm and categorical equipment economic lifetimes documented in DCAC 600-60-1, Chapter 32.

Cost elements other than those addressed above were treated only on a qualitative basis during the remainder of the study. Selected cost factors that appear to be significant with regard to the P/M concept implementation were identified, and their relative cost behavior under the P/M concept versus the conventional configuration was predicted, based on engineering judgment and experience in life cycle cost analyses.

3.2.2.3 Cost Element/Activities Relationship

Table 3-5 illustrates the relationship between the eleven cost elements and eleven transition activities. As can be seen, the costs of the eleven transition activities will be reflected in four cost elements. The remaining cost elements will be addressed as discussed in Section 3.2.2.1.

3.2.3 Transition Cost Estimate

The following section provides an estimate of the cost of the current deployment concept versus the P/M concept for transition scenarios A and C. The transition scenarios and associated activities were defined in Section 3.2.1 and the cost elements, their application, and their relationship to the transition scenario activities were discussed in Section 3.2.2. Table 3-6 summarizes the quantity, unit cost, and weight for the C-E equipment and cabinets/racks considered in the analysis of the transitions.

TABLE 3-5. COST ELEMENTS/ACTIVITY MATRIX

Cost Element	1. Conduct on-site engineering	2. Plan the move	3. Plan the cutover	4. Assemble & test new equip. prior to shipment	5. Package equip. for shipment to new site	6. Ship equip. to new site	7. Disassemble existing site equip.	8. Assemble, install, & test new site equip.	9. Cut over new site equip.	10. Package existing site equip. for shipment	11. Ship existing equip. to storage
PME Acquisition*											
Aux. equip. acquisition*											
Integration and assembly (In-plant)				X							
Contractor training*											
Peculiar & common spt. equip.*											
System test & eval.*											
System/project mgt.	X	X	X						X		
Data*											
Operational/site act. (on-site)							X	X			
Initial spares/repair parts*											
Transportation					X	X				X	X

*See remarks in Section 3.2.2.1

TABLE 3-6. TRANSITION C-E EQUIPMENT COSTS AND WEIGHTS

	Equipment Quantity					
	Trans. A (Table 2-7)	Trans. C (Table 2-11)	Unit Cost[(1)] (Table 3-3)	Unit Wt.[(1)] (Table 2-3)	Cab/Rack Cost, $ (Table 3-4)	Cab/Rack Weight, lb (Table 2-3)
RF Equipment						
AN/FRC-170	1	2	39,000	265	70	340
AN/FRC-162	1		48,154	455	2,800	455
First Level Multiplex						
CY-104A	8		22,000	200	245	385
AN/FCC-98(TD-1192)	15	6	21,000	100	198	245
Second Level Multiplex						
AN/FCC-97	1		20,000	108	245	290
AN/FCC-99(TD-1193)	2	4	16,500	105	214	270
Other Equipment[(2)]						
Walburn	2					
TPTB	1	2				
FAS Ops		1				
Pwr Sup Gp		1				

(1) Exclusive of equipment cabinet or rack.

(2) All "other equipment" excluded from analysis due to unknown unit cost, weight, and/or dimensions.

All "other equipments", such as cryptographic equipment and patch and test bays were excluded from this analysis due to the lack of sufficient data to estimate their unit cost, weight, or dimensions.

3.2.3.1 Prime Mission Equipment

Although no comparison is made between total PME costs for the P/M and conventional approaches, these costs are used in the derivation of other costs. The following total C-E equipment costs are used, based upon the data in Table 3-6:

a. Transition A, C-E equipment cost = $631,154

b. Transition C, C-E equipment cost = $270,000.

The above costs do not include cabinets and/or racks; therefore, the following costs are estimated for the comparison of the two concepts in transitions A and C. Table 3-7 illustrates the transition cabinet/rack costs for each concept and the number of pallets required to implement the P/M concept for each transition. The cabinet/rack costs for the conventional concept were taken directly from Table 3-4. For the P/M concept, a single standardized cabinet is used. In those instances where actual equipment dimensions permit, equipment have been combined into a single cabinet resulting in an overall cost savings for the P/M concept. This grouping is especially effective for the new digital equipment, which requires less space. It should be noted that cabinets two bays wide are available from certain manufacturers at a savings of approximately $20 from the cost of two separate cabinets. Savings in weight are dependent on the height. However, since such a two-bay cabinet may not be required for each pallet, these potential cost and weight savings were not considered in this analysis. The following summarizes the cabinet/rack costs:

Transition	Total Cost ($) Conv. Approach	Total Cost ($), P/M Approach
A	8,473	7,230
C	2,184	2,120

Also included in Table 3-7 are the total number of pallets required to implement the P/M concept for each transition. Two equipment cabinets are mounted on each pallet while maintaining system integrity (i.e., AN/FRC-162 and its associated multiplex are grouped separately from the AN/FRC-170 and its associated multiplex). Approximating the unit cost for pallets in quantities of 2,000 at $460, the following summarizes the pallet costs:

Transition	Total Pallet Cost ($)
A (11 pallets)	5,060
C (4 pallets)	1,840

TABLE 3-7. TRANSITION CABINET/RACK AND PALLET COSTS

Conventional Concept				P/M Concept					
		Cost ($)				Cost ($)		Pallets	
Equipment	Racks	Each	Total	Equipment	Racks	Each	Total	Qty	Cost ($)*
TRANSITION A									
CY-104	8	245	1,960	CY-104	8	265	2,120	4	1,840
AN/FCC-97	1	245	245	AN/FCC-97	1	265	265	} 1	460
AN/FRC-162	1	2,800	2,800	AN/FRC-162	1	1,665	1,665		
AN/FCC-98	15	198	2,970	AN/FCC-98	8	265	2,120	4	1,840
AN/FCC-99	2	214	428	AN/FCC-99	2	265	530	1	460
AN/ FRC-170	1	70	70	AN/FRC-170	2	265	530	1	460
Total			8,473	Totals			7,230	11	5,060
TRANSITION C									
AN/FCC-98	6	198	1,188	AN/FCC-98	3	265	795	} 4	1,840
AN/FCC-99	4	214	856	AN/FCC-99	2	265	530		
AN/FRC-170	2	70	140	AN/FRC-170	3	265	795		
Total			2,184	Totals			2,120	4	1,840

*Pallet unit cost of $460 assumed based on production quantity of 2,000.

From the above total, PME acquisition costs are as follows:

Cost Element	Trans. A Cost ($) Current	Trans. A Cost ($) P/M	Trans. C Cost ($) Current	Trans. C Cost ($) P/M
C-E equipment	631,154	631,154	270,000	270,000
Cabinets/racks	8,473	7,230	2,184	2,120
Pallets		5,060		1,840
Total PME Cost	639,627	643,444	272,184	273,960

3.2.3.2 Integration and Assembly (I&A)

Integration and assembly (I&A) costs (Activity 4, Table 3-5) are estimated as ranging from 5 percent to 20 percent of the total PME acquisition cost. A factor of 5 percent is used for routine systems using standard equipment, while a factor of 20 percent is used for new systems requiring integration using equipment developed by many different manufactures. The I&A costs are expected to be similar between the two concepts, with the following exceptions:

a. Conventional concept – This concept may require more cables and connectors than the P/M concept since each C-E equipment item is expected to be installed in a separate cabinet. Further, once acceptance testing at the factory is complete, the C-E equipment in the conventional concept is disassembled in order to ready the equipment for subsequent packing and shipment.

   1) Transition A – Based upon the above discussion, the I&A costs are estimated to be 10 percent of the total PME costs. Although this transition includes new equipment I&A, this 10 percent factor was used since the I&A considered slightly more complex than for a routine system (i.e., 5 percent as noted above), but does not represent that degree of complexity for multiple manufactured systems (i.e., 20 percent).

   2) Transition C – This I&A cost element is not applicable to this scenario (see Table 3-2).

b. P/M concept – This concept permits the integration of similar equipment onto a single pallet, such as first and second level multiplex or multiplex and radio equipment, thus reducing the costs for lengthy cables and conduits. Further, no disassembly is required prior to packing and shipment. However, this cost element must consider the cost of providing a flooring cover for each of the pallets.

   1) Transition A – I&A costs are estimated to be 5 percent of the total PME costs, plus the cost of pallet covers at $5 per square foot for 6 square feet, for a cost of $30 per pallet.

2) Transition C — I&A costs not applicable. The pallet surfaces are costs that would be considered sunk since this scenario assumes that the C-E equipment is preassembled and in storage awaiting deployment.

Therefore, I&A costs are as follows:

	Trans. A Cost ($)		Trans. C Cost ($)	
Cost Element	Current	P/M	Current	P/M
I&A	63,963	31,981	(Not applicable)	
Pallet surface		330		
Total I&A Costs	63,963	32,311	0	0

3.2.3.3 System/Project Management

This cost element includes the following four activities from Table 3-5:

Activity Number	Activity Title
1	Conduct on-site engineering
2	Plan the move
3	Plan the cutover
9	Cut over new site equipment

From Table 3-2, activities 1, 3, and 9 are conducted during Transition A and activity 2 is included in Transition C. Chapter 20 of DCAC 600-60-1 suggests the use of a factor of 10 percent each for system management and project management.

System/project management costs are expected to be similar between the two concepts and the two transition scenarios, except that the conventional concept for Transition Scenario A will require additional effort to 1) plan the relocation and placement of equipment assembled in individual cabinets/racks, 2) prepare a bill of materials for each equipment interconnection from separate cabinets, and 3) plan and accomplish the cutover and provide for the subsequent removal of site equipment. No difference has been identified in the cost of planning the move (activity 2) between the two concepts for Transition Scenario C, since in both concepts the equipment is preassembled and ready for deployment. System/project management costs are derived as follows:

a. Conventional Concept

1) Transition A — Based upon the above discussion, activities 1, 3, and 9 are estimated to be 18 percent of the total PME costs. A factor of 18 percent rather than 20 percent was used since management costs are not expected to be equal to those of a major system acquisition.

2) Transition C – Cost for activity 2 is estimated to be 5 percent of the total PME costs. A lower factor was selected since this transition consists of only one major activity rather than the broad range of management support needed in Transition A.

b. P/M Concept

1) Transition A – The combination of activities 1, 3, and 9 are estimated to be 12 percent of the total PME costs. Savings are realized due to the fact that the equipment is preassembled and integrated onto a single pallet requiring less on-site engineering, little or no requirement for a bill of materials, and minimal cutover effort.

2) Transition C – Cost for activity 2 is estimated to be 5 percent of the total PME costs.

Therefore, system project management costs are as follows:

Cost Element	Trans. A Cost ($) Current	Trans. A Cost ($) P/M	Trans. C Cost ($) Current	Trans. C Cost ($) P/M
Activities 1, 3 & 9	115,133	77,213		
Activity 2			13,609	13,698

3.2.3.4 Data

As discussed in Section 3.2.2, data costs are applicable only to the implementation of the P/M concept. Data costs for the conventional concept were assumed to have been previously expended, and are therefore considered sunk. Data costs for implementation of the P/M concept are as follows:

a. Pallet full data package: 9($460) = $4,140 ($2.07 per pallet for a nominal pallet production quantity of 2,000).

b. Revised C-E equipment documents:

Equipment	Cost Equation	Total Data Cost ($)	Cost per Pallet ($)*
AN/FRC-170	0.5(39,000)	19,500	9.75
AN/FRC-162	0.5(48,154)	24,077	12.0385
CY-104A	0.5(22,000)	11,000	5.5
AN/FCC-98	0.5(21,000)	10,500	5.25
AN/FCC-97	0.5(20,000)	10,000	5.
AN/FCC-99	0.5(16,500)	8,250	4.125
Total Costs		83,327	41.6635

*Assumes a nominal pallet production quantity of 2,000.

Therefore, additional data costs for implementation of the P/M concept are as follows:

Cost Element	Trans. A Cost ($), 11 Pallets	Trans C Cost ($), 4 Pallets
Pallet data package	23	8
Revised C-E equip. data	458	167
Total	481	175

3.2.3.5 Operational Site Activation

This cost element addresses those activities associated with assembly, installation, and checkout (AI&C). Costs for contractor technical support and site construction were assumed to present no significant cost differences between the P/M and conventional approaches. Costs for AI&C include the costs for activities from Table 3-5:

Activity	Description
7	Disassemble existing site equipment.
8	Assemble, install, and test (AI&C new site equipment.

From Table 3-2, both of the above activities occur during Transition Scenario A, while only activity 8 occurs during Transition Scenario C.

a. Conventional Concept – The disassembly of existing site equipment is expected to be similar to the assembly cost of 10 percent of the total acquisition cost of PME. The DCAC factor for the AI&C of new site equipment at a normal, easily accessible site is 40% of the total cost of PME, while AI&C of a transportable facility is 20 percent.

   1) Transition A – Using the above factors, activities 7 and 8 are estimated to cost 10 percent and 40 percent of PME cost, respectively.

   2) Transition C – Activity 8 is estimated to cost 20 percent of PME cost.

b. P/M Concept – For Transition Scenario A, the disassembly of existing site equipment is expected to be similar to the P/M assembly cost of 5 percent; however, the cost of AI&C of the new site equipment is expected to be considerably lower for the P/M concept than the conventional concept. DCAC experience reflects costs of 20 percent of PME costs in those instances where the assembly is performed in the vendor's plant. For Transition Scenario C, the P/M concept is expected to provide a slight advantage over the conventional concept due to minimum set-up and interconnections.

   1) Transition A – Using the above rationale, activities 7 and 8 are estimated at 5 percent and 20 percent of PME cost, respectively.

2) **Transition C – Activity 8 is estimated at 15 percent.**

Operational site activation costs are therefore as follows:

Operational Site Activity	Trans. A Cost ($)		Trans. C Cost ($)	
	Current	P/M	Current	P/M
Disassemble existing site equipment	63,963	32,172		
AI&C of new site equipment	255,851	128,851	54,437	41,094
Total Opr. Site Cost	319,814	160,861	54,437	41,094

3.2.3.6 Transportation

The transportation cost element includes the following four activities from Table 3-5:

Activity	Activity Description
5	Package equipment for shipment to new site.
6	Ship equipment to new site.
10	Package existing equipment for shipment.
11	Ship existing equipment to storage.

From Table 3-2, it can be seen that all of the above activities are included in Transition Scenario A, while only activity 6 occurs in Transition Scenario C. The conventional concept is expected to incur additional costs in packaging over the P/M concept due to the requirement to individually package each C-E equipment subsystem. Conversely, the P/M concept will have higher shipment costs to the added weight of the pallet and weight differences of the cabinets and racks.

Table 3-8 summarizes the equipment shipping weights for each transition. Unit shipping weight of each C-E equipment was estimated from data collected in Task 1 and includes the weight of an equivalent cabinet or rack. Unless provided in the Task 1 data, cabinet and rack weights were derived from the same manufacturers' catalogs used to estimate their costs. The weight of the standard cabinet envisioned for the P/M concept is 200 pounds. An additional 50 pounds was added to the AN/FRC-162 standard cabinet for shielding.

Transition A assumes that the new equipment is packed and crated at the factory, shipped from the factory to east coast port of departure, air lifted to Frankfurt, Germany, and locally transported to the DCS site a distance of 200 miles away. Existing equipment recovered from the site is returned via the same route; however, it is shipped to a depot for salvage.

TABLE 3-8. TRANSITION SCENARIO SHIPPING WEIGHTS

Equipment	Qty	Shipping Weight (lb) Each	Shipping Weight (lb) Total	Equipment	Qty	Shipping Weight (lb) Each	Shipping Weight (lb) Total
TRANSITION A							
CY-104	8	385	3,080	CY-104	8	400	3,200
AN/FCC-97	1	290	290	AN/FCC-97	1	305	305
AN/FRC-162	1	455	455	AN/FRC-162	1	430**	430
AN/FCC-98	15	245	3,675	AN/FCC-98	15	300	4,500
AN/FCC-99	2	270	540	AN/FCC-99	2	305	610
AN/FRC-170	1	340	340	AN/FRC-170	1	495	495
				Pallets	11	100	1,100
Total Shipping Weight			8,380	Total Shipping Weight			10,640
(Requires one 3.5 to 6.25-ton truck at $0.19/mile)				(Requires one 3.5 to 6.25-ton truck at $0.19/mile)			
TRANSITION C							
AN/FCC-98	6	245	1,470	AN/FCC-98	6	300	1,800
AN/FCC-99	4	270	1,080	AN/FCC-99	4	305	1,220
AN/FRC-170	2	340	680	AN/FRC-170	2	495	990
				Pallets	4	100	400
Total Shipping Weight			3,230	Total Shipping Weight			4,410
(Requires one 1.6 to 3.5-ton truck at $0.16/mile)				(Requires one 1.6 to 3.5-ton truck at $0.16 mile)			

*Standard P/M concept cabinet is assumed to weigh 200 lb.

**Includes 50 additional pounds for shielding.

Transition C assumes that the equipment being deployed required only local transport of 200 miles from storage to the new location. Packing or further shipment are not required in this scenario.

a. Conventional Concept

1) Transition A — Based on Table 24-9 of DCAC 600-60-1, activities 5 and 10 are estimated at 3.5 percent and 6.2 percent of equipment cost, respectively. Activities 6 and 11 are estimated in the following three transport phases:

a) CONUS shipment to/from port of departure = 3 percent of equipment costs, based on Table 24-9 of DCAC 600-60-1.

b) Air lift to/from Frankfurt, Germany = (0.555) (Equip. Weight), based on Table 24-10 of the above document.

c) Local transport in Europe = Vehicle costs given in Table 24-12 of the above document.

2) Transition C — Table 24-12 from DCAC 600-60-1 is used to estimate local transportation cost (see summary table below).

b. P/M Concept

1) Transition A — Activities 5 and 10 are estimated at 2 percent and 3.5 percent of equipment cost, respectively, due to minimal amount of packing and crating of palletized equipment. Activities 6 and 11 are estimated using the same factors as the conventional concept, with the additional weight of the pallets included in the total weight of the equipment. The above assumptions and factors result in the following costs for transportation:

Activity	Trans. A Cost ($) Current	Trans. A Cost ($) P/M	Trans C Cost ($) Current	Trans C Cost ($) P/M
Package equipment for shipment (Activity 5)	22,386	12,869	N/A	N/A
Ship equip. to new site (Act. 6):				
Ship to port of departure	19,188	19,303	N/A	N/A
Air lift to Frankfurt, Germany	4,651	5,905	N/A	N/A
Local transport	38	38	32	32
Package existing equip. for shipment (Activity 10)	39,657	22,521	N/A	N/A
Ship existing equip. to storage (Activity 11)				
Local transport to port of departure	38	38	N/A	N/A
Air lift to CONUS	4,651	5,905		
Shipment to depot	19,188	19,303		
Total	109,797	85,882	32	32

3.2.4 Cost Drivers/Differences and Time Savings

Table 3-9 provides a summary of the economic implications of the conventional and P/M concepts for transition scenarios A and C. The total cost of each transition scenario suggests that savings may be realized through implementation of the P/M concept. The following paragraphs highlight the cost drivers, differences, and time savings inherent in the economic analysis for each concept.

3.2.4.1 Conventional Concept

The cost drivers of the conventional concept for Transition Scenario A, and to some degree for Scenario C, are:

Activity	Description
4	Integration and Assembly – In Plant
5, 10	Packaging
7	Disassembly
8	Assembly, installation, and checkout – on site

Each of the above activities appears to expend resources (manpower and material) at a rate twice that estimated for the P/M concept. All of the above cost drivers are a direct result that each C-E system is repeatedly assembled, integrated, disassembled, and packaged. Such handling is expensive, especially in terms of the manpower needed to complete each task.

No time savings could be identified in any activity as a result of using the conventional rather than the P/M concept. A slight cost advantage of the conventional concept was noted in only the cost areas of: shipment to port/depot.

3.2.4.2 P/M Concept

The cost drivers of the P/M concept for those transition scenarios addressed include those costs associated with the production, documentation, and shipment of the pallet. These costs, however, are relatively insignificant when compared to the overall reduced activity costs for integration, assembly, and packaging. Further, cost reductions may be realized in cabinets/racks through integration and assembly of like C-E equipment into one or two cabinets on a pallet.

Time savings as a result of implementation of the P/M concept can be expected in the following transition activities:

Activity	Description
1, 2	Conducting on-site engineering and planning moves.
3, 9	Planning and conducting cutovers.
8	Assemble, install, and test site equipment – Activity 8.
7	Disassembly of site equipment.
5, 10	Packaging.

TABLE 3-9. TRANSITION SCENARIO COST SUMMARY

Cost Element	Trans. A Cost ($)		Trans. C Cost ($)	
	Conv.	P/M	Conv.	P/M
C-E Equipment	631,154	631,154	270,000	270,000
PME				
Cabinets/Racks	8,473	7,230	2,184	2,120
Pallets		5,060		1,830
Integration & Assembly				
I&A (Act. 4)	63,963	31,981		
Pallet Surface		330		
System/Project Management				
On-site engrg. & cutover (Act. 1, 3, 9)	115,133	77,213		
Plan the move (Act. 2)			13,609	13,698
Data				
Pallet data package		23		8
Revised C-E eq. data		458		167
Operational Site Activation				
Disassemble existing equip. (Act. 7)	63,963	32,172		
AI&C new site equip. (Act. 8)	255,851	128,689	54,437	41,094
Transportation				
Package equip. for shipment (Act. 5)	22,386	12,869		
Ship equip. to new site (Act. 6)	23,877	25,246	32	32
Package existing equip. (Act. 10)	39,657	22,521		
Ship existing equip. to storage (Act. 11)	23,877	25,246		
Total Cost	1,248,334	1,000,192	340,262	328,959

3.2.5 Other Costs

This section provides an assessment of other costs that may be experienced in the implementation of the P/M concept which were not addressed in Section 3.2.3. These other costs include:

a. Salvage or residual value of recovered equipment

b. Pallet research and development

c. Pallet annual operating costs

d. Pallet integrated logistics support.

The above costs are discussed in the following paragraphs.

3.2.5.1 Salvage (Residual) Value

The economic analysis of the Transition Scenarios A and C, presented in Section 3.2.3, while providing for an assessment of the key activities common to most transition scenarios, did not consider the salvage or residual value of existing equipment recovered or lost during a forced or contingency removal of a site.

To demonstrate the potential salvage value, the scenario for Transition E (Foreign government-forced closure of a major site) was used, and the C-E equipment used in the economic analysis for Transition Scenario A is assumed to constitute the site complement of equipment.

Chapter 32 of DCAC 600-60-1 provides for the economic assessment of salvage (or residual) value of equipment. This document provides the following formula to estimate residual value:

$$R = \frac{(a-b)}{a} S$$

where:

R = residual value

a = economic life in years

b = years in use to date

S = purchase price (plus inflation factor)

For the analysis, it was assumed that the site equipment had been deployed for four years at the time the site closure occurs; therefore the value for parameter b above is 4. Table 32-1 of DCAC 600-60-1 provides the average economic life (in years) for various types of equipment. From this table, LOS microwave has an economic life of 13 and multiplex of 8 years. However, this reference suggests that the category of

equipment that represents the largest part of a single, integrated facility may be used to estimate the life of the complete facility. Finally, the purchase price (less the cost of cabinets, racks, and pallets) without inflation was used since the objective of the analysis is to compare the economic implications of the two concepts rather than to estimate actual salvage value.

Transition Scenario E imposes the constraints that 1) no station capabilities can be deactivated until 7 days prior to closure, and, 2) at least 25 percent of the station channels must be kept active until 3 days prior to closure. In keeping with these constraints, an examination of the station complement suggests a deactivation schedule as presented in Table 3-10. This schedule reflects that more than one-third (10 of the 28) items of C-E equipment accounting for nearly 40 percent ($251,654) of the original cost of the equipment must be disassembled, packed, and shipped in only 3 days. Under the conventional concept, it is doubtful that these 10 items can be totally recovered, considering the 18 items to be removed in the 4 days prior to this final closure period. Experience suggests that all activities associated with a forced closure would have to be accomplished by site O&M personnel without the assistance of other station or external personnel. Further, site personnel reductions would gradually decrease the complement of personnel to some minimum number needed to maintain critical communication services. Finally, although not addressed in Table 3-10, the remaining cryptological equipment and associated classified material would have to be removed in this final period prior to any other C-E equipment. Therefore, for the conventional concept, it is assumed that only the first-level multiplex (two each CY-104 and four each AN/FCC-98 could be disassembled, packed, and shipped during the final closure period. Thus it is assumed that the following C-E equipment would be abandoned on-site:

Nomenclature	Qty.	Cost
AN/FCC-97	1	$ 20,000
AN/FRC-162	1	48,154
AN/FCC-99	1	16,500
AN/FRC-170	1	39,000
Total		$123,654

It is considered feasible to remove the entire set of 10 equipments during the last remaining period of 3 days if no packing or crating were performed. Such an approach would likely result in some damage and/or loss to the equipment either during disassembly or shipment. This equipment would then require some degree of rehabilitation at a depot prior to its subsequent use.

Assuming that the four equipments above were abandoned on-site, this would result in the loss of their residual (or salvage value). The residual loss and asset recovery for the conventional concept are as follows:

$$R = \frac{(13-4)}{13} (\$123,654) = \$85,607 \text{ (loss)}$$

$$R = \frac{(13-4)}{13} (\$507,500) = \$351,346 \text{ (recovery)}$$

TABLE 3-10. RESIDUAL VALUE ANALYSIS

Percent Station Complement				Deact. 7 Days Prior to Closure		Deact. 3 Days Prior to Closure	
		Cost ($)					
Nomenclature	Qty.	Unit	Total	Qty.	Total Cost ($)	Qty.	Total Cost ($)
CY-104	8	22,000	176,000	6	132,000	2	44,000
AN/FCC-97	1	20,000	20,000			1	20,000
AN/FRC-162	1	48,154	48,154			1	48,154
AN/FCC-98	15	21,000	315,000	11	231,000	4	84,000
AN/FCC-99	2	16,500	33,000	1	16,500	1	16,500
AN/FRC-170	1	39,000	39,000			1	39,000
Totals	28		631,154	18	379,500	10	251,654

Under the P/M concept, there is no apparent reason why the entire complement of site equipment cannot be removed during the closure period. The modules essentially need to be disconnected and loaded onto a vehicle. No further packing or crating is required if the equipment is to be air lifted, other than some cover to protect it from extreme environmental conditions. Using the P/M concept results in the following residual asset recovery:

$$R = \frac{(13-4)}{13} (\$631,154) = \$436,953 \text{ (recovery)}$$

Thus the net difference between the conventional and P/M site equipment recoveries would be in excess of $85,000.

3.2.5.2 Pallet Research and Development

It appears that little or no research and development funds will need to be expended to mature the design of the pallet, since the P/M concept has been essentially validated and documented. However, to clearly establish the feasibility and economic implications of the P/M concept, it may be prudent to build several prototype pallets to be used in an operational test of the P/M concept. Such a test could be used to demonstrate the P/M concept in an operational environment while permitting an accurate measure of cost and time savings against the conventional concept. The cost to conduct such a test would include the cost of prototype pallets and manpower to perform and measure the various activities described above the the transition scenarios. The prototype pallet unit cost should approximate the first unit cost of $506 each as estimated in Section 3.1.5 of this report. The various activities could be performed and measured using both permanent and transportable facilities at Ft. Huachuca's Electronic Proving Ground.

3.2.5.3 Pallet Annual Operating Costs

Figure 2 of DCAC 600-60-1 suggests four major areas of annual operating cost:

a. Military personnel

b. Operations and maintenance

c. Recurring investment

d. Operating support.

3.2.5.3.1 Military Personnel. With the implementation of the P/M concept, savings rather than additional costs should occur in military personnel to perform those various activities associated with the hypothezied transition scenarios.

3.2.5.3.2 Operations and Maintenance (O&M). The DCA Circular separates O&M into eight cost areas; Civilian Personnel, TDY and Civilian PCS, Transportation of Things, Utilities and POL, Contractor Employees, Building Maintenance, Supplies and Equipment, and Miscellaneous Support. Transportation of Things has already been

addressed in the report (see Section 3.2.3.6), and implementation of the P/M concept is not expected to appreciably add to POL costs due to the pallet's relatively light weight. As with military personnel above, savings should be realized in both civilian personnel and contract employees costs.

The requirement for supplies and equipment has been briefly discussed. Such supplies and equipment encompass:

a. Fixtures to mount the equipment on pallets

b. Nuts, bolts, and washers to attach the equipment to the pallets to each other

c. Shims to level the pallets

d. Dollys, hydraulic lifters, or forklifts to move or position the pallets

e. Cleaning supplies for upkeep of the pallet surface area.

Since such supplies and equipment are not required on a continuing basis, they are not expected to exceed the DCAC annual factor of 3 percent of the equipment cost.

3.2.5.3.3 Recurring Investment. Since the pallet as currently designed does not include any spare parts or parts subject to replacement, there should be little or no recurring investment cost. The pallets may require occasional painting to maintain their cosmetic appearance. Further, the surface area suggested for the pallets to provide a false floor may need some refurbishment over the life of the pallets. Finally, the pallets are essentially immune to abandonment, pilferage, or other factors that might require their subsequent replacement.

3.2.5.3.4 Operating Support. This cost area includes the following six major operating support costs:

a. Base operations

b. Depot maintenance

c. Recruiting and basic training

d. Hospitals

e. Military PCS travel

f. Other indirect costs.

The only one of these cost categories expected to be impacted through the implementation of the P/M concept is depot maintenance. As previously suggested, preassembled C-E equipment on pallets may impact upon depot costs for the repair, modification, testing, storage, or rehabilitation of C-E equipment. The palletized equipment may increase the repair, modification, testing, or rehabilitation costs due to the requirement to disassemble such equipment prior to any depot maintenance

action. However, any additional cost is not considered significant since depot maintenance costs are currently estimated at an annual rate of 0.005 and 0.025 of the C-E equipment cost for fixed site and transportable equipment, respectively. Storage at the depots of the pallets with or without mounted C-E equipment is expected to be minimal.

3.2.5.4 Pallet Integrated Logistics Support

The CORADCOM Cost Estimating Handbook (Methods and Factors) include four categories of operating costs; personnel, consumption, integrated logistics support (ILS), and depot maintenance. These cost areas, except for ILS, were discussed in Section 3.2.5.3. This reference defines the ILS cost element as those costs attributable to inventory management, including supply studies, requisitioning costs, cataloging, provisioning studies, and costs of holding inventory. Procedures are provided for estimating the cost of entering and maintaining an NSN in the Army inventory, and of holding inventory.

Using the above estimating procedures and factors, the cost for entering and maintaining an NSN for the pallet is $542 the first year (including introduction costs) and $236 annually thereafter, in FY77 dollars. The cost of holding inventory includes the storage cost and other losses. Storage costs are estimated at less than 1 percent per year of the cost of the pallets being stored. Other losses due to pilferage, shrinkage, and inventory adjustment are not considered applicable to the pallets.

Chapter 4
FUTURE APPLICATIONS OF THE P/M CONCEPT

Task IV is concerned with recommendations for design improvements for second and third generation C-E equipments to facilitate expansion of the P/M concept in the DCS. A related concern is to develop guidelines for new DCS facilities and installations to facilitate potential application of the P/M concept. The objectives of such design recommendations and guidelines include:

a. Minimizing equipment/module interconnectivity problems

b. Improving equipment capability to be modularized

c. Promoting rapid, simple operational setup and recovery under field deployment and use conditions.

4.1 GENERAL CONSIDERATIONS

The concept of palletization/modularization opens up new opportunities for C-E equipment packaging. The opportunity to consider a full cabinet as a housing for assembling and integrating component parts of an equipment system or subsystem removes many current constraints and provides many benefits. The existing constraints imposed by size, shape, and weight limitations for discrete units (e.g., amplifiers, power supplies, control panels, and multiplexer units) frequently are compounded by requirements for interconnecting cabling and plugs, and for convenient access thereto, in various installations. The implementation of the P/M concept, allowing extensive assembly at the factory and shipment in a largely assembled form, relieves designers of added packaging constraints imposed by shipping, handling, and on-site assembly requirements of discrete units.

Lost space and the added weight of the discrete boxes and covers may be at least partly recovered by using the clear internal space of the P/M cabinet to optimally arrange and position equipment components. Improved air flow around components may be developed by the elimination of unit covers or by less restrictive form factors, providing a uniformly cooler environment for the electronics. A cooler environment, combined with solid-state technologies, will typically improve reliability. Accordingly, C-E equipment packaging can exploit the opportunities inherent in the P/M concept to increase factory integration levels, enhance equipment reliability, and reduce costs and weight.

The developers of DCS C-E equipments for application in the 1990s timeframe will be able to combine anticipated component and system technology advances with the increased packaging flexibility described above to increase the level of integration achieved in a single module. Since the DCS is transitioning to a configuration based upon digital architecture, digital component advances will have a marked impact on the size of 1990s DCS equipment. Technologies such as very large-scale integration (VLSI), multi-chip wafers with built-in standby spares, and bubble memories are approaching operational application today. It is anticipated that in the 1990s these and others, as yet unknown, technologies will be widespread in DCS-type equipments.

The impact of these technology applications on the size of DCS equipments has not been estimated quantitatively during this study. However, digital electronics history of the past five years implies that the impacts during the next 10-15 years will be at least order-of-magnitude decreases in all-digital components. The pocket calculator offers a familiar example of such results in recent years. The Hewlett-Packard Model 45 calculator, when introduced on the marketplace around 1975, led the industry with its scientific capabilities. The coat-pocket size unit required battery recharging after 3-5 hours of operation, and retailed for $395 (FY74 dollars). In 1978, 5 years later, Casio introduced their fx-48 credit card calculator. The size of a credit card and approximately 0.1-inch thick, the unit provides capabilities nearly identical to the HP-45, operates for approximately 600 hours from a battery included inside the thin case, and retails for $39.95 (FY79 dollars).

If it is reasonable to consider similar packing and cost factors applied to DCS equipments, then switches, multiplexers, encryption units, and other functional elements are likely to be compacted to sizes whereby entire stations may be mounted on one or a few relatively small pallets. If such compaction could be combined with corresponding reduction in electro-optical multiplexer/demultiplexer and transmission devices, total station integration might be accomplished with small numbers of fiber-optic cables between small numbers of modules. Assuming that adequate module handling equipment was available at sites, the resultant site installation or retrieval times would be reduced well below those possible with current techniques or the 1980s upgrade P/M concept described earlier.

Additional study activities are required to adequately and quantitatively assess the potential benefits offered by technology advances for the 1990s DCS. Such studies should emphasize the investigation of new, innovative architectures for DCS stations, developed specifically to enhance the level of integration possible with a P/M concept and drastically reduce station setup and takedown times. However, before such a study could be conducted, the context of the study and the P/M applications will require further definition.

The specific intended applications and objectives of the 1990s module must be defined for, or as part of, the study. The study will have to consider how and where such advanced modules would be used in the DCS of the 1990s. This question must address whether the modules would be deployed 1) only to create new or expanded station capabilities; 2) mainly to upgrade the flexibility of existing portions of the DCS; 3) to reconfigure portions of the DCS; 4) as replacements for outmoded or failing equipments; or 5) some combination of all of these. A concept must also be developed for how (if at all) such advanced modules would have to interface with or be interoperable with existing DCS networks.

In defining the objectives and operating concepts of the modules, the study must consider such factors as:

a. How fast must a new site be made operational by means of the advanced P/M concept? (Must a station be operational 24 hours after delivery of the equipment to this site?)

b. Must the concept provide full station capability, or can it be restricted to only portions of the functions at a DCS station?

c. What operational and deployment constraints will or will not be allowed to drive the design/configuration of the modules? (If large, heavy modules are hypothesized, can it be assumed that suitable forklifts can be made available at the installation site under contingency conditions? How many personnel can be anticipated to form the installation/removal crews? How long will the equipment be operational on-site, and consequently what level of sparing provisions is required? Will the modules be stored at some location for contingency deployment (a technique which has not proven very successful in the past), or will modules be extracted from one part of the DCS to augment others?)

The definition of these considerations and the establishment of other necessary assumptions and constraints will be a critical aspect of the early phase of any study of advanced modules.

DCS planning considerations and constraints must also be established early in the effort. Is a total network upgrade to advanced module configuration to be performed? Over what period of time? If a partial upgrade is desired, which sites will be involved and what is the schedule? What new sites or capabilities are to be added, and when? What is the plan for transitioning service from the old stations to the new, advanced module equipments? Are there any known budgetary constraints on the upgrade?

All of the above considerations and others, must be addressed prior to or during the advanced module study, as all of them will impact the resultant concept and the assessment of its feasibility. While some should be addressed prior to the study and imposed on the advanced module as requirements, it may be desirable to leave others as tradeoff parameters for the study. The decisions regarding those parameters can then be made at the end of the study, based partly on their determined impact on the module concept.

4.2 C-E EQUIPMENT RECOMMENDATIONS

During the analysis of the 1980s P/M concept feasibility and scope of applicability, as well as the development of pallet design recommendations, certain areas were noted that represent either restrictions on applicability or opportunities for improvement. While some anticipated technology advances would appear to offer potential for increased applicability of the P/M concept, care must be exercised in recommending their future use in specific equipments. It is generally preferable to address performance or configuration objectives, leaving design implementation and technology selection to the competitive motivation of industry. In fact, user or buyer pressures calling for improved results or equipment characteristics can often lead to technology innovations, while user statements oriented toward specific identified technologies may actually repress creative searches for breakthroughs. For these reasons, the recommendations cited here are expressed in relatively general terms oriented toward objectives rather than dictated solutions.

4.2.1 DRAMA Radio Configuration

The current specified configuration of the DRAMA AN/FRC-170 radio unit comprises a set of components stacked vertically in a single rack. The height of the rack required for that radio exceeds the rack/cabinet height recommended for the

DCS modules (based on transport and doorway constraints). Discussions with DRAMA development engineers have indicated that minor specification and design changes would allow mounting the radio set in two shorter racks, side by side. In order to allow use of the DRAMA radio in the P/M concept, it is recommended that such specification and design changes be made.

4.2.2 RF Connector Location

It is common practice in many cabinet or rack-mounted RF units to locate RF connectors for waveguides or bulky/stiff cables at the tops of units. This allows routing of the cables or waveguides over cabinet bays, avoiding equipment obstruction, damage to the RF conductors, etc. Any future DCS RF units should be specified so as to prevent RF connectors from protruding higher than the 57-inch cabinet height during shipment. Such protrusions would be subject to damage in tight fits through doorways, and could preclude the use of RF modules in some facilities or vans/shelters.

4.2.3 Equipment Heights

Shipping and doorway height restrictions led to a recommendation for 57-inch high cabinets/racks for the P/M concept. All future C-E equipments intended for P/M deployment should be specified as mountable in one or more such cabinets/racks.

4.2.4 Cabinet Dimensions

Current equipment cabinets are typically 26-inches deep. Much of the C-E equipment identified in this study is considerably less than 26-inches deep, resulting in much empty space at the back of cabinets and substantially off-center loads. Also, typical 57-inch cabinets full of equipment were found to weigh considerable less than the allowable load for a pallet. Future advances in microelectronic applications to DCS equipments may decrease both the weight and required depth of equipment even more.

It is therefore recommended that a double-faced cabinet configuration be investigated for DCS P/M use. The cabinet would measure 22"W x 57"H x 44"D, thereby spanning the full 44-inch depth of a pallet. Two such cabinets mounted side by side would make full use of the surface area of a pallet. Both faces of the cabinet would be open and configured as a conventional 19-inch mounting cabinet. Thus C-E equipments could be assembled facing both front and back of a pallet. The individual components could be mounted on staggered extension slides to permit maintenance and cable attachment by pulling any unit out from the cabinet. This would decrease the number of modules to be shipped and handled for a site installation, allow a higher level of factory integration of modules, and increase deployment and recovery speed. The larger cabinets would also provide increased opportunity for new, less restrictive equipment configuration designs, taking advantage of increased form factor options.

4.2.5 Switch Configuration

A major equipment area excluded from consideration in the study was that of large network switches. With increasing emphasis on digital transmission and switching networks, along with technology advances (LSI, VLSI, bubble memories, etc.),

new switch configurations and implementations may be possible which would make their palletization practicable. An investigation of this area should be conducted to determine both the feasibility and preferred direction of such new switch configurations for P/M application.

4.2.6 Uninterruptible Power Supplies

The large banks of lead-acid batteries currently used as backup power source at DCS sites were identified as equipment not readily amenable to P/M concept application. New battery technologies, or other types of stand-by energy sources, should be examined to determine their applicability to DCS sites and their suitability for P/M deployment. Substantial advances have been made recently in battery technology, and research in the general field of energy sources is likely to increase in the near future. (An example of recent battery development is the Lithium cell work being performed by the Army. The cells offer striking improvements in power-to-weight ratios over other battery types, and safety problems appear to have been surmounted by built-in current limiting devices in each cell. Anticipated high production volumes for widespread application are expected to reduce the cost of the cells to a cost-effective level for fully militarized units.)

4.2.7 Standardized Connectors

Standardization of connector types specified for modules and C-E equipment would at least enhance the application of the P/M concept, if not increase its scope of applicability. Such standardization would 1) decrease site engineering time, 2) increase installation speed by reducing unanticipated mismatches and improving installation crew familiarity with equipments, 3) increase the mobility or redeployment flexibility of modules, 4) decrease sparing requirements, and 5) increase procurement quantities (for unit cost reduction). Care must be exercised in keying connectors to ensure that intra-pallet standardization of connectors does not result in potential assembly/integration cabling errors.

4.2.8 Distribution Frames

Main distribution frame developments, as indicated in COM-TC09-001, August 1977, are attempting to exploit pre-assembly and internal wiring (at the depot) in order to minimize on-site installation time and effort. As noted earlier in Section 2.3.1.5, there is limited potential application of the P/M concept to such distribution frame assemblies in the near term. Whereas, in the not too distant future, offshoots of the solid state EPABX developments are expected to handle the distribution frame functions with many advantages. For example, the elimination of manual access to effect interconnection changes can be accompanied by processor-controlled printouts to replace the hand corrections of drawing lists of the changes as they are implemented. The cable runs of the existing distribution frames, and the pre-assembled types (COM-TC09-001), as well as the projected variants of the EPABX type will be accommodated in the P/M concept by the open channel recessed at the back of the pallets. Thus, a palletized EPABX-type distribution frame can be set into a bay lineup and connected to the inplace cable runs or disconnected and removed without disturbing the established cable run.

4.2.9 Waveguides

Waveguide runs are expected to be used largely as in present day practice. Examination of the P/M concept considered the possibilities of accommodating runs in and through the pallets, but the costs and engineering requirements were excessive. The practice of top-side mounting of the waveguides as exemplified most recently in the DRAMA radio (AN/FRC-170) is fully compatible with the cabinet-pallet construction for the P/M concept.

4.3 DCS FACILITY RECOMMENDATIONS

Although relatively little detail regarding DCS facilities was available to this study, some aspects of the study results and the recommended pallet concept were derived from facilities considerations. However, few significant constraints on P/M implementation were derived from facilities characteristics alone, and therefore few areas have been identified where facility design modifications would enhance the P/M concept or its applicability. Several suggestions are provided below.

4.3.1 Doorway and Passageway Dimensions

One of the bounding constraints on pallet size was the requirement to fit through a 48-inch door opening and to be easily maneuvered inside buildings. Specification of larger doors and ample interior passageways would allow for somewhat larger pallets. Increasing pallet size by approximately one foot in at least one dimension would facilitate bottom and side access for bolting and cable feed-through if the larger cabinet of Section 4.2.4 was adopted. It would also allow the larger cabinet to be greater than 44-inches deep, if desired.

The practicability of increasing pallet size substantially beyond the current 44" x 44" recommendation, however, is limited by factors other than new facility access doors and hallways. These factors include:

a. On-site handling difficulty if size and weight increase.

b. The relatively small number of C-E items to be upgraded at any one site in the 1980s time period.

c. Decreased partial upgrade installation flexibility as pallet size increases.

d. The need for the P/M configuration to be compatible with many existing DCS facilities for many years in the future.

4.3.2 Elevators

No specific problems or constraints were identified in the study as a result of elevator capacities at DCS sites. However, this was due to a lack of quantitative data identifying the existence or characteristics of multi-story facilities and elevators. Any future sites which contain elevators should be equipped with large freight elevators of a capacity and door size which will not constrain P/M configurations more severely than any other requirements do. (Floors above ground level should also be specified to carry loads compatible with module movement and installation.)

4.3.3 Outdoor Ramps and Walks

As the modules are intended for on-site movement by manual "walkie" pallet lift devices, any new or upgraded facilities should not require up or down movement of modules on steps or steep slopes. Transport vehicle access (typically truck; possibly helicopter to remote sites) should be provided to hard-paved surfaces, onto and over which the modules can be manually wheeled after off-loading from the vehicle. Surfaces should be smooth and bump/ridge/crack-free to allow ease of movement and avoid high shock levels caused by hard wheels encountering such obstacles. The ease of manual movement is especially important at remote sites, such as mountain-top relays, as mechanized aid is often not available at such sites.

4.3.4 Power Outlets

Power outlets, conduits and distribution of power in new DCS sites, i.e., new construction, will warrant significant consideration in the design and planning process, and will be affected by the extent of projected P/M concept implementations, i.e., equipment types and groupings. Power considerations in existing facilities are not expected to be affected by the P/M concept implementation. The premise for powering the P/M modules is that local site/facility electrical power of the types needed by the module equipment will be brought to fully visible unobstructed access connectors at or in the module(s) by one or more suitable cables, passing through troughs, recesses or openings in the pallet as required. This approach simplifies the pallet design and provides the module packaging engineer more latitude in arranging equipment elements in the assembly of the module. In addition, this approach facilitates the actual separation of the routing of the power wires and signal wires in or through the pallets.

4.3.5 New Facility Requirements

The construction of new DCS site facilities such as described by the document, Combined Communications Building, Kanto Plain, Japan (24 May 1978), reflects considerations of future requirements. For example, the building would be underground and would have walls of a minimum thickness of 12-inches of reinforced concrete. It would be a large structure as required to house an AUTODIN switch. It would have high ceilings as well as a raised floor (2-1/2 feet above the subfloor) to accommodate signal cable ducts and power ducts, with the air conditioning supply and return ducts in the false ceiling overhead. The working area height for C-E equipment bays would be 10 feet high from the false floor to the false ceiling. In this context, assuming amply large equipment entry doors, the C-E equipment cabinets could well be 6 feet 8 inches tall or taller. However, it is questioned whether this building is or could be representative of future DCS site facilities. The sheer number of existing DCS sites (581) essentially precludes a one-for-one replacement on the basis of cost alone. Their very number, assuming satellite relay and alt-routing capabilities are exploited, is excellent assurance of some degree of DCS survivability in any context. Their continued existance in some large numbers is reasonable to expect, so that the future facilities context for P/M concept implementation in the 1990s is likely to be similar to the present one. Accordingly, the design constraints and requirements drivers used in initializing the P/M approach should continue to be largely applicable. In any event, the suggested pallet and cabinet design is a point of departure for trial, evaluation, modification, etc. as time and funds permit, and potential benefits continue.

Floor loading factors and requirements in new DCS facilities are difficult to state precisely, given the uncertainties in electronic equipment packaging densities in the 1990s and the possible ultimate size of advanced modules offering higher levels of integration. It does not appear likely that the maximum weight of an individual cabinet filled with C-E equipment will exceed (or even equal) the maximum weight of a filled cabinet today, assuming that microelectronics are employed extensively to compact equipments. Some amount of open space in and around cabinet-mounted items will still be required for cable runs, maintenance access, heat dissipation, etc. These requirements will tend to bound the maximum weight of equipment which can be placed in one cabinet. (Recent studies by ARINC Research to develop cost estimating relationships and integration data for Air Force and Navy electronic units have indicated little variation in weight-per-volume characteristics of such equipments designed and fabricated over a period of years.) Thus, for modules placed in their final positions on the facility floor, the total effective loading factors are not likely to equal or exceed today's standards of 150 lb/ft^2.

If future facility doorway heights are on the order of 8 feet, cabinet heights on the order of 6-1/2 feet would be allowable. Such tall cabinets, combined with higher levels of module integration and utilization of blank spaces now common in many DCS racks, could lead to higher weight loads per square foot. Individual cabinet weights on the order of twice those currently experienced might be realized, especially if the double-faced cabinet configuration of paragraph 4.2.4 were adopted. This approach could lead to somewhat increased floor loadings, perhaps on the order of 200 lb/ft^2. Facility flooring specifications would need to reflect such loads in areas where DCS C-E modules would be located.

Movement of modules into, out of, and within facilities could also create floor loading problems in aisles, passageways, and loading dock areas. These problems would be more or less severe, dependent upon the in-facility movement technique used. Use of hard-wheeled dollies or "walkies" can concentrate the module weight onto small floor areas. However, such manual devices are generally used for limited weight items, and would not be practical for modules of the ESS 3 size and weight. Facility floors, therefore, would need only to tolerate wheel loadings imposed by maximum "walkie" load capacities, the same as they currently are. As these capacities are largely designed around human factors for ability to move and control the "walkie", they would not be expected to change with time.

If forklift trucks are used in facilities to handle large, advanced modules, floor loading could be greater than currently experienced. Forklifts of greater capacity (e.g., up to 50,000 lbs.) are being developed and fielded by the military. The availability of such equipment at DCS sites could lead to the movement of large modules approaching these weights in and out of the facilities. Insufficient data are available regarding tire contact area, etc., for such forklifts to allow a quantitative definition of the resultant floor loads. However, it appears that the potential for high-weight loading offers sufficient risk that maximum local loading data for such trucks should be located and considered in future facility designs.

The use of some type of air cushion devices for movement of modules at DCS sites appears to offer protection against excessive local floor loading. By distributing the module weight evenly over the area of the air cushion, concentration of stress on flooring materials is avoided. A simple air cushion platform for handling large modules might be devised which could be left in place under the module at the DCS site. This would allow immediate movement of the module for site reconfiguration or equipment removal, although it would effectively increase the cost of the module slightly. It would also relieve the loading capacity requirement for facility flooring.

For the sake of being able to maneuver large modules into place within a DCS facility of the future, it is recommended that large access doors open directly from loading docks into the room where the C-E equipments are to be installed. Floor plans should not require movement of equipment through hallways or aisles to reach the installation location. The rooms should be large enough to allow handling equipment to reach all modules individually after they have been placed in their final locations. There should also be sufficient maneuvering space to allow the removal of any individual module (for site reconfiguration or relocation of the module to another site) without having to move any other module.

It is anticipated that the P/M concept, applied in its ultimate advanced form during the 1990s, will greatly reduce the numbers and sizes of cables to be run throughout a DCS site. Increased numbers of functions mounted on a single module will allow module-to-module interfaces to be selected at points in the station configuration where (for example) a single fiber optic cable with associated multiplexer/demultiplexer equipment can provide the entire signal connection required on site. With this decrease in cabling required at sites, and advantages such as non-interference of power and signal conductors when using fiber optics, the problem of separating power and signal cables should be greatly reduced. This in turn will result in a decrease in facility construction requirements related to cabling trays, troughs, shielded ducting or conduit, etc.

141

Appendix A
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MIL-HDBK-411	Electrical Power
AFSC-DH 1-11	Air Transportability Design Handbook

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MIL-STD-188-310	Subsystem Design and Engineering Standards for Technical Control Facilities
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MIL-STD-188-317	Equipment Technical Design Standards for High Frequency Radio
MIL-STD-188-340	Equipment Technical Design Standards for Voice Orderwire Multiplex
MIL-STD-188-342	Equipment Technical Design Standards for Voice Frequency Carrier Telegraph (FSK)
MIL-STD-188-347	Equipment Technical Design Standards for Digital End Instruments and Ancillary Devices
MIL-STD-188 Series	Common Long Haul and Tactical Communications System and Subsystem Technical Standards
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Appendix B

ORGANIZATIONS AND INDIVIDUALS CONTACTED

The individuals listed below were the principal study contacts for their organizations. Many others provided helpful assistance, including making arrangements to see the knowledgeable individuals.

1. USACEEIA, U.S. Army Communications-Electronics Engineering Installation Agency, Ft. Huachuca, AZ

Colonel H.J. Walther	Director, Communications Engineering Directorate
Mr. P.B. Loux, Jr.	Supervisor, Electrical Engineering
Mr. Pat Tufts	Chief, Switched Systems Division
1st Lt. Mio Lazarevich	Study COR, Systems Integration
Mr. Julian Saenz	Chief, Project Engineering Branch
Mr. Dick Hartman	DRAMA, Radio (COR)
Mr. Bob Elsner	DRAMA, MUX (COR)

2. USACC, U.S. Army Communications Command, Ft. Huachuca, AZ

Mr. William Abolt	Study Action Officer, DCS/OPS, CC-OPS-PT

3. USACSA, U.S. Army Communications System Agency, Ft. Monmouth, NJ

Lt. Col. Robert Ed	Deputy Manager for R&D Programs, CSA
Mr. B. McLaughlin	Study Project Manager, CCM-RD

4. DCA, Defense Communications Agency, DCEC, Reston, VA

Lt. Col. Earl E. Webb	Chief, Facilities and Operations Branch, DCEC
Mr. Paul Baiter	Study Sponsor/Coordinator, DCEC-R320
Mr. Andrew Izzo	Fiber Optics Studies

5. Communications-Electronics Services Division, USACC, Pentagon

Colonel Roy Shrout	Former Chief, DCS Facilities and Operating Engineering Section, DCEC, and originator of study requirement

6. Joint Technical Communications Office (TRI-TAC), Pentagon

Mr. Casey Zwart	Vice Director

7. TRI-TAC Equipment Engineering Division, Ft. Monmouth, NJ

Mr. Robert Badger	Assistant to Division Chief
Mr. Nick Pagnanelli	Logistics Management Directorate

8. Joint Test Element (TRI-TAC), Ft. Huachuca, AZ

Lt. Col. Hessler	Chief, Test Services Facility

9. Command and Control Technical Center, DCA Building, Arlington, VA

Mr Benham Morris	Director (Acting), Deputy Director

10. U.S. Army Materiel Development and Readiness Command, DARCOM, Alexandria, VA

Mr. James Burdette	DSSA-ALOC

11. CERCOM/CORADCOM/DARCOM, Ft. Monmouth, NJ

Mr. Jules Sagui	Chief, Shelters Facility and Assembly Section
Mr. Ludwig	Chief, CERCOM Shelter Development Laboratory

12. U.S. Army Natick R&D Command, DARCOM, Natick, MA

Mr. Al Carletti	Chief, Tactical Shelter Branch and Secretary of JOCOTAS Committee for DoD

13. Sharpe Army Depot, DARCOM, Lathrop, CA

Major Dull	Chief, West Coast Consolidation and Containerization Division

14. Travis Aerial Port, Travis AFB, Fairfield, CA

Mr. George Volgar	Assistant Officer in Charge, Air Freight

15. Materiel Division, Hqs. Marine Corps, Commonwealth Building, Arlington, VA

Colonel James Harp	Director, Field Logistics Systems Dimensional Standardization
Mr. Daniel Rene	Shelters and Subsystems Manager, Installations and Logistics Department

16. U.S. Navy Logistics System Coordination, Hqs. Marine Corps, CWB

Commander Heyward Boyce	Coordinator, Field Logistics System

17. <u>MITRE Corporation, Bedford, MA</u>

Mr. Ed Sullivan	Technical Staff, Project Engineer
Mr. George Fagan	Manager, Packaging Development Programs

18. <u>ARINC Research Corporation, Annapolis, MD</u>

Colonel Noel Smith (Ret.)	Secretary, USAF Avionics Planning Conference (for new equipment development programs)
Mr. Armand Bilodeau	DARCOM and Army Transportation Studies
Mr. Pat Dallosta	U.S. Army Container Consolidation Studies
Mr. William Kolb	Commercial Telco Installations Studies
Mr. Ben Paiz	Former E-8, DCS (STRATCOM) 1962-71
Mr. Al Simmons	Former W.O., DCS (STARCOM/USACC HQ) 1962-76

19. <u>Craig Systems Corporation, Fullerton, CA</u>

Mr. Roger Noebel	Field Engineer

20. <u>Ground Systems Group, Hughes Aircraft Company, Fullerton, CA</u>

Mr. Shelton T. Kales	Senior Technical Staff

21. <u>Satellite Ground Systems Laboratory, Hughes Aircraft Company, Los Angeles, CA</u>

Mr. Les Gustafson	Manager, Test Systems Department
Mr. B. Berne	Senior Staff Mechanical Engineer
Mr. M.D. Miwa	Manager Test Systems

22. <u>TRW-VIDAR Division, Mountain View, CA</u>

Mr. George L. Curtis	Digital Network Specialist

23. <u>ALL-BANN Enterprises Inc., Anaheim, CA</u>

Mr. Sid Bann	Proprietor

24. <u>Thiem Industries, Inc., Torrance, CA</u>

Mr. P. Adams	Manufacturing Manager

Appendix C
DCS SITE PROFILES (ARMY-NAVY-AIR FORCE)

DCS SITE PROFILES — ARMY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
1																			X			X		
2															X	X					X	X	X	X
3																			X			X		
4															X						X	X	X	
5															X						X	X	X	
6		X													X				X	X	X	X		X
7															X						X	X	X	
8																	X				X	X	X	
9															X							X		
10															X				X			X		
11															X				X		X	X	X	
12															X				X		X	X		X
13															X						X	X	X	
14															X				X			X		
15																			X			X		
16	X														X	X			X		X			X
17							X									X				X	X	X	X	
18															X						X	X	X	
19										X					X					X	X			
20																			X			X		
21	X														X	X			X		X	X		X
22																			X			X		
23															X							X		
24																			X			X		
25			X																	X			X	
(cont.)																								

DCS SITE PROFILES — ARMY

	Voice Switches					Record Switches					Transmission Media									Support Services				
DCS Sites	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
26															X						X	X		X
27															X						X			X
28															X						X	X		X
29															X						X	X	X	
30															X							X		
31																			X			X		
32															X						X			X
33		X						X								X				X		X	X	X
34															X						X	X	X	
35															X									
36																			X			X		
37															X				X		X	X	X	
38															X				X		X	X		X
39															X						X	X	X	
40																			X			X		
41															X	X					X	X		X
42															X						X	X		X
43																			X			X		
44															X		X				X	X		
45															X							X		
46				X											X				X	X	X	X		
47															X							X		
48															X						X	X	X	
49																X						X		
50																			X			X		
(cont.)																								

DCS SITE PROFILES — ARMY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
51															X							X		
52			X		X															X		X		
53															X						X	X		X
54																			X			X		
55																			X		X	X	X	
56															X						X	X	X	
57																			X		X	X		
58															X							X		
59							X													X		X	X	
60										X					X	X				X	X	X		X
61													X		X						X	X	X	
62														X							X	X	X	
63															X	X					X	X		X
64															X							X		
65																			X			X		
66															X				X			X		
67															X	X					X	X		X
68																			X			X		
69															X						X	X	X	
70																			X			X		
71															X						X			X
72																			X			X		
73																			X			X		
74				X											X				X		X	X		X
75															X				X		X	X	X	X
(cont.)																								

DCS SITE PROFILES — ARMY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
76															X						X	X		
77					X			X						X	X						X	X		X
78															X						X			
79													X		X						X	X	X	
80																			X			X		
81		X								X										X			X	
82															X	X					X	X		X
83															X							X		
84															X						X	X		X
85																			X			X		
86			X												X					X	X	X		
87															X						X	X	X	
88															X						X	X		
Totals	2	3	3	2	2	0	2	2	0	3	0	0	2	2	58	11	2	0	34	10	50	79	27	23

DCS SITE PROFILES — ARMY

	Voice Switches					Record Switches					Transmission Media									Support Services				
DCS Sites	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
1															X						X	X	X	
2															X						X	X	X	
3															X				X		X	X		X
4			X																	X				
5															X						X			X
6															X						X	X	X	
7															X						X	X		
8															X	X					X	X		X
9															X						X	X		X
10															X							X		
11															X							X		
12																			X		X	X		X
13															X						X		X	
14					X										X					X	X	X	X	
15															X						X	X	X	
16															X	X					X			X
17			X		X															X		X		
18															X	X					X	X	X	
19															X						X	X	X	
20															X						X	X	X	
21												X			X						X	X		
22															X						X	X	X	
23															X						X	X	X	
24															X				X		X			X
25															X						X	X	X	
(cont.)																								

DCS SITE PROFILES — ARMY

	Voice Switches					Record Switches					Transmission Media									Support Services				
DCS Sites	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
26															X						X	X		X
27	X				X		X					X			X	X	X			X	X	X	X	X
28																X								
29															X	X					X	X		X
30			X		X						X					X				X	X	X		
31															X	X					X	X		X
32															X				X		X	X		X
33															X						X	X	X	
34															X				X		X	X	X	
35																			X			X		
36															X						X		X	
37																			X		X			X
38																			X		X	X		X
39															X						X	X	X	
40												X	X								X	X		
41												X		X							X	X		X
42															X						X	X	X	
43											X				X	X					X	X	X	
44															X							X		
45															X						X	X	X	
46											X				X						X	X		
47															X						X	X		X
48															X	X					X		X	
49															X						X	X	X	
50															X						X	X	X	
(cont.)																								

DCS SITE PROFILES — ARMY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
51																			X		X	X		X
52															X						X			
53															X					X	X	X		X
54															X						X	X		
55															X						X	X	X	
56															X	X					X	X		X
57																	X				X	X		
58															X						X	X		X
59															X						X	X		X
60															X						X	X	X	
61															X						X	X	X	
62															X						X	X		X
63			X		X										X	X				X	X			X
64															X						X	X		
65															X						X	X	X	
66															X						X	X	X	
67															X							X		
68															X						X	X	X	
69															X							X	X	
70															X						X	X		
71			X													X				X		X	X	
72															X						X	X		
73															X	X					X	X		
74																	X				X	X	X	
75							X									X				X	X	X		X
(cont.)																								

DCS SITE PROFILES — ARMY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
76															X	X					X	X		
77															X						X	X		X
78	X				X										X						X	X		X
79				X	X										X	X					X	X	X	
80			X																	X		X		
81															X						X	X	X	
82															X				X		X	X		X
83															X						X		X	
84															X						X	X	X	
85			X	X	X						X									X	X	X	X	X
86															X					X	X			
87															X						X	X		X
88															X				X		X	X		X
89															X	X					X	X		X
90															X						X	X	X	
91															X						X	X		X
Totals	2	0	7	2	8	0	2	0	0	0	4	4	1	1	74	18	3	.0	11	12	80	78	38	32

DCS SITE PROFILES — ARMY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(US/CZ)																								
1			X																	X				
2			X																	X		X		
3			X																	X				
4		X				X									X					X	X	X	X	X
5															X							X		
6																	X				X	X		X
7			X																	X		X		
8			X																	X				
9															X						X	X		X
10			X																	X				
11			X																	X				
12			X																	X				
13			X																	X		X		
14							X										X			X	X	X	X	X
15			X																	X				
16			X																	X	X	X		X
17			X																	X				
18			X																	X				
19		X																		X		X	X	
20				X		X				X										X	X	X		X
21															X							X		
22															X							X		
23			X																	X				
24							X													X		X		
25																	X				X	X		
(cont.)																								

DCS SITE PROFILES — ARMY

	Voice Switches					Record Switches					Transmission Media									Support Services				
DCS Sites	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(US/CZ)																								
26															X						X			X
27															X							X		
28			X																	X				
29															X						X	X	X	
30			X																	X				
31			X																	X				
32			X																	X				
Totals																								
(US/CZ)	0	3	18	1	0	2	2	0	0	1	0	0	0	0	8	0	3	0	0	23	9	17	4	7
(Pacific)	2	0	7	2	8	0	2	0	0	0	4	4	1	1	74	18	3	0	11	12	80	78	38	32
(Europe)	2	3	3	2	2	0	2	2	0	3	0	0	2	2	58	11	2	0	34	10	50	79	27	23
Grand Totals	4	6	28	5	10	2	6	2	0	4	4	4	3	3	140	29	8	0	45	45	139	174	69	62

DCS SITE PROFILES — NAVY

DCS Sites	Voice Switches: SCA	SVS	SVX	TSB	TSM	Record Switches: ADR	DIN	MDX	TAX	TMX	Transmission Media: CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	Support Services: BOR	MUX	PRX	PTF	TCX
(Europe)																								
1													X	X	X							X	X	
2										X									X		X	X	X	
3										X					X					X	X			X
4															X						X		X	
5		X													X					X	X	X		X
6		X													X					X	X	X	X	X
7													X		X		X		X		X	X	X	
8														X	X						X	X	X	
9															X						X	X	X	
10															X						X	X	X	
11															X						X	X	X	
12										X			X		X						X	X	X	X
13														X	X						X	X	X	
14													X						X		X	X		X
15														X					X		X		X	
16													X		X						X	X		X
17														X	X						X	X	X	
18														X	X						X	X		X
19													X		X						X	X	X	
20															X							X		
21															X							X		
22															X							X		
23															X						X	X		
24															X						X	X	X	
25															X									
Totals	0	2	0	0	0	0	0	0	0	3	0	0	6	6	22	0	1	0	4	3	20	21	15	7

DCS SITE PROFILES — NAVY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
1			X										X		X	X				X	X	X		
2														X	X	X			X		X			
3															X						X	X	X	
4				X	X											X					X	X		
5															X						X	X	X	
6										X			X								X	X		X
7														X							X	X	X	
8																	X				X	X		
9	X						X								X	X				X	X	X	X	X
10															X						X	X	X	
11														X	X						X	X	X	
12															X						X	X	X	
13													X								X	X	X	
14																X	X				X		X	
15															X						X		X	
16										X					X					X	X	X		X
17														X							X		X	
18													X		X						X	X	X	
19														X								X		X
20													X									X	X	
21															X						X	X		X
22															X						X	X	X	
23															X						X	X	X	
24							X				X		X		X	X	X			X	X	X	X	X
25																								
(cont.)																								

DCS SITE PROFILES — NAVY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
26														X	X						X	X		
27															X						X			
28															X						X	X	X	
29															X						X	X	X	
30															X						X	X	X	
31		X	X													X				X		X	X	
Totals	1	1	2	1	1	0	2	0	0	2	1	0	6	6	20	7	3	0	1	5	27	25	20	6

DCS SITE PROFILES — NAVY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(US/CZ)																								
1							X													X		X	X	
2								X		X			X	X						X		X		X
3										X					X						X	X		X
4										X					X						X	X	X	
5															X							X		
6															X							X		
7			X																	X				
8			X							X										X				
9															X						X	X		
10										X					X						X	X	X	X
11															X						X	X		
12															X						X	X		
13																	X				X	X	X	
14		X																		X	X	X		X
15														X								X	X	
16													X									X	X	
17															X									
18														X	X						X	X	X	
19															X						X	X		
20								X												X		X		
21								X							X	X				X	X	X	X	X
22													X		X	X					X	X	X	
23														X	X						X	X	X	
24														X								X		
25			X																	X				
(cont.)																								

DCS SITE PROFILES — NAVY

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(US/CZ)																								
26		X	X			X									X					X	X	X	X	X
27															X		X				X		X	
28										X				X	X						X	X	X	
29													X									X	X	
30			X																	X				
31			X																	X		X		
32															X						X	X		
33															X						X	X	X	
34															X						X	X	X	
35													X		X						X	X	X	
36			X			X														X	X	X		X
37															X						X	X	X	X
38														X	X						X	X	X	
39															X						X	X		
40															X							X		
41													X		X						X	X	X	
42															X						X	X	X	
43															X						X	X	X	
44															X						X	X	X	
45															X						X	X		
46															X						X		X	
Totals																								
(US/CZ)	0	2	7	0	0	2	1	3	0	6	0	0	6	7	31	2	2	0	0	12	30	39	24	8
(Pacific)	1	1	2	1	1	0	2	0	0	2	1	0	6	6	20	7	3	0	1	5	27	25	20	6
(Europe)	0	2	0	0	0	0	0	0	0	3	0	0	6	6	22	0	1	0	4	3	20	21	15	7
Grand Totals	1	5	9	1	1	2	3	3	0	11	1	0	18	19	73	9	6	0	5	20	77	85	59	21

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
1															X						X	X	X	
2															X						X	X	X	
3															X						X	X		X
4															X							X		
5															X						X	X		
6															X						X	X		
7															X						X	X		X
8																			X		X	X	X	
9															X	X					X	X		X
10															X							X		
11															X						X	X	X	
12															X						X	X		
13															X						X	X	X	
14															X						X	X	X	
15											X					X					X			
16															X							X		
17															X							X		
18															X						X	X	X	
19															X						X	X	X	
20															X						X		X	
21															X				X		X	X	X	
22																			X		X	X	X	
23										X					X						X	X	X	X
24													X										X	
25							X													X		X	X	
(cont.)																								

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
26														X	X						X	X	X	
27															X							X		
28																	X				X	X	X	
29															X							X		
30															X						X			X
31															X				X		X	X	X	
32																	X				X	X	X	
33															X						X	X		
34															X				X		X	X		X
35															X						X	X	X	
36																			X		X	X	X	
37	X														X	X					X	X	X	X
38															X							X		
39															X							X		
40															X							X		
41															X							X		
42															X							X		
43															X							X		
44															X							X		
45															X							X		
46															X						X		X	
47																			X		X			X
48															X						X	X	X	
49															X						X	X	X	
50															X							X		
(cont.)																								

DCS SITE PROFILES — AIR FORCE

	Voice Switches					Record Switches					Transmission Media									Support Services				
DCS Sites	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
51				X				X							X						X	X		X
52	X														X	X					X	X		X
53															X							X		
54															X							X		
55															X							X		
56	X														X	X			X		X	X		X
57					X					X			X	X	X					X	X	X		X
58																			X		X	X	X	
59															X						X	X		X
60															X				X		X	X	X	
61															X						X	X	X	
62															X						X	X	X	
63															X						X	X	X	
64															X						X	X	X	
65															X							X		
66															X				X		X	X	X	
67																			X			X		
68		X	X	X					X						X				X	X	X	X	X	
69	X														X	X					X	X		X
70															X				X		X	X		
71			X	X	X										X					X	X	X		X
72															X				X		X	X	X	
73															X							X		
74			X												X				X	X	X	X		X
75															X				X		X	X	X	
(cont.)																								

DCS SITE PROFILES – AIR FORCE

	Voice Switches					Record Switches					Transmission Media									Support Services				
DCS Sites	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
76															X						X		X	
77																			X		X	X	X	
78															X				X		X	X	X	
79															X						X	X		X
80															X						X	X		X
81															X				X		X		X	
82															X							X		
83															X				X		X	X		X
84																			X		X	X	X	
85	X														X	X			X		X	X		X
86															X							X		
87															X				X		X	X		X
88	X														X	X			X		X	X		X
89	X														X	X			X		X	X	X	X
90											X				X	X					X	X		X
91															X						X	X	X	
92																			X			X		
93																			X		X	X	X	
94															X							X		
95															X						X	X		
96		X			X										X	X				X	X	X		X
97															X						X	X		
98		X													X				X	X	X			X
99																			X		X	X	X	
100															X				X		X	X		X
(cont.)																								

DCS SITE PROFILES — AIR FORCE

	Voice Switches					Record Switches					Transmission Media									Support Services				
DCS Sites	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Europe)																								
101															X				X		X	X	X	
102	X														X	X			X		X	X		X
103															X							X		
104															X							X		
105															X						X	X		
106															X						X	X		
107		X													X					X	X	X		X
108			X												X					X	X	X	X	
109															X						X	X	X	
110															X				X		X	X	X	
111															X						X	X	X	
112															X						X	X	X	
113															X							X		
114															X						X	X		X
115															X							X		
116															X						X	X		X
117															X						X		X	
118															X						X		X	
119																			X			X		
120															X						X		X	
121															X				X		X	X		X
122															X						X	X		
123															X						X			
124															X						X	X		
Totals	8	4	4	3	3	0	1	1	1	2	2	0	2	2	107	12	2	0	36	9	92	111	52	32

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
1			X												X	X				X	X	X		X
2															X						X	X	X	
3																			X		X			
4																			X			X		
5																X	X				X	X	X	
6			X		X					X			X		X	X				X	X	X	X	X
7	X						X								X	X				X	X	X	X	
8															X				X		X	X		
9																						X		
10							X								X	X				X	X	X	X	X
11															X						X	X	X	
12				X											X		X				X	X		X
13				X	X									X	X						X	X	X	
14															X						X	X	X	
15	X			X											X	X			X		X			X
16															X				X			X		
17															X						X	X		X
18															X				X		X	X		X
19					X										X						X	X		
20															X				X		X		X	
21				X								X				X							X	
22			X		X										X	X				X	X	X		X
23					X						X					X					X	X		
24															X						X	X	X	
25															X							X		
(cont.)																								

DCS SITE PROFILES — AIR FORCE

	Voice Switches					Record Switches					Transmission Media									Support Services				
DCS Sites	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
26															X							X		
27			X		X											X				X				
28												X									X	X		
29															X						X	X	X	
30															X						X	X	X	
31															X							X		
32															X						X		X	
33			X													X				X				
34															X						X	X	X	
35			X																	X		X		
36																			X			X		
37															X						X	X	X	
38															X				X		X	X	X	
39			X												X			X		X	X	X		
40															X						X	X		X
41															X				X		X	X		
42					X																			
43															X							X		
44															X						X	X	X	
45															X						X	X		X
46															X							X		
47																		X			X			
48																			X					
49			X												X	X				X	X	X	X	X
50															X						X	X	X	
(cont.)																								

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(Pacific)																								
51															X						X	X	X	
52				X											X						X	X	X	
53															X						X	X	X	
54				X											X						X	X	X	
55			X												X	X				X	X	X		X
56															X						X	X	X	
Totals	2	0	9	5	7	0	2	0	0	1	1	2	1	1	42	13	4	0	11	11	41	46	25	12

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(US/CZ)																								
1							X								X					X	X	X	X	X
2													X		X						X		X	
3														X	X						X	X	X	
4															X							X		
5															X						X			
6			X																	X				
7																			X		X		X	X
8			X																	X				
9		X																		X		X		
10				X																		X		
11																			X		X		X	
12																			X		X		X	
13					X														X		X		X	X
14																			X		X		X	
15																			X		X		X	
16																			X		X		X	
17			X																	X				
18																			X		X		X	
19																			X		X		X	
20																			X		X		X	
21			X																	X				
22			X																	X				
23																			X		X		X	
24																			X		X		X	
25																			X		X		X	
(cont.)																								

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(US/CZ)																								
26																			X		X		X	
27															X	X			X		X	X	X	X
28			X																	X				
29			X																	X				
30		X														X	X			X	X	X	X	
31							X													X		X	X	
32																			X		X		X	
33			X																	X				
34			X																	X				
35																			X		X		X	
36																			X		X	X	X	
37			X																	X				
38																			X		X		X	
39			X																	X				
40			X																	X				
41																			X		X		X	
42															X		X				X	X		X
43														X	X						X	X		
44													X		X						X	X		
45																			X		X		X	X
46			X																	X				
47																			X		X		X	
48																			X		X		X	
49			X																	X				
50			X																	X				
(cont.)																								

25

(cont.)

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
(US/CZ)	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
51			X																	X	X	X		X
52														X							X	X		
53													X								X	X		
54			X																	X		X		
55			X																	X		X		
56			X																	X		X		
57			X																	X				
58							X													X		X		X
59																			X		X		X	
60			X																	X		X		
61																	X							
62																			X		X	X		X
63																			X		X		X	
64				X																		X		
65			X				X													X		X		X
66		X																		X		X		
67																			X		X		X	
68			X																	X			X	
69				X																		X		X
70																			X		X		X	
71			X												X					X	X			X
72			X																	X				
73																			X		X		X	
74																			X		X		X	
75			X																	X		X		
(cont.)																								

	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
Totals	1	1	2	1	1	0	2	0	0	2	1	0	6	6	20	7	3	0	1	5	27	25	20	6

DCS SITE PROFILES — AIR FORCE

DCS Sites	Voice Switches					Record Switches					Transmission Media									Support Services				
	SCA	SVS	SVX	TSB	TSM	ADR	DIN	MDX	TAX	TMX	CLX	CSX	HRX	HTX	LSX	LLC	SYT	SAT	TRX	BOR	MUX	PRX	PTF	TCX
(US/CZ)																								
76			X																	X				
77			X																	X				
78																			X		X		X	
79																			X		X		X	
80																			X		X	X	X	
81			X														X			X	X			
82															X						X	X		X
83															X				X		X	X	X	
84			X				X													X		X	X	
85																			X		X		X	
86			X																	X		X		
87																			X		X		X	
88			X																	X				
Totals (US/CZ)	0	3	32	3	1	0	5	0	0	0	0	0	3	3	11	2	4	0	36	38	50	31	43	13
(Pacific)	2	0	9	5	7	0	2	0	0	1	1	2	1	1	42	13	4	0	11	11	41	46	25	12
(Europe)	8	4	4	3	3	0	1	1	1	2	2	0	2	2	107	12	2	0	36	9	92	111	52	32
Grand Totals	10	7	45	11	11	0	8	1	1	3	3	2	6	6	160	27	10	0	83	58	183	188	120	57